MECHANICAL DRAWING.

ELEMENTARY AND ADVANCED.

BY

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FOURTH EDITION, REVISED AND ENLARGED.
FIRST THOUSAND.

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PREFACE TO THE FOURTH EDITION.

THE third edition of "A Course in Mechanical Drawing" was enlarged and improved by the addition of a set of concrete problems, "A Course in Lettering" and "Present Practice in Drafting Room Methods."

In this, the fourth edition, the work has been further enlarged and improved by adding courses in Advanced Mechanical Drawing consisting of short elementary courses in Advanced Isometrical Drawing, Architectural Drawing, Sheet Metal Drafting, Machine Details, and Working Drawings made from freehand sketches of small machine parts.

This arrangement will preclude the necessity of using several text-books in high schools, manual-training high schools, university preparatory schools, technical colleges, and evening classes where a variety of courses are given to meet the needs of students preparing for different trades and professions.

With the addition of these new courses in advanced work it has been thought desirable to change the title of the book from "A Course in Mechanical Drawing" to "Mechanical Drawing, Elementary and Advanced."

It was very gratifying to the writer to learn that the improvements in the third edition were well received by both teachers and students and it is hoped that the additions to the fourth edition will meet with a like approval.

JOHN S. REID.

PREFACE TO THE THIRD EDITION.

To MEET the demands of high schools, manual training high schools, university preparatory schools, technical colleges, and evening classes, it has been found necessary to add to "A Course in Mechanical Drawing" a concrete set of problems covering the full requirements in mechanical drawing for entrance to the more advanced classes in machine drawing, elementary machine design, and architectural drawing. The minimum time allowed in a definite number of working hours for the finishing of each plate, as introduced in this edition, is a new feature, and will be much appreciated by Instructors when determining the amount of work to require from their students in a given term. The time allowed for the different plates has been carefully determined by taking note of the actual number of hours taken by large numbers of students working on the same plates, under the same conditions, and a conservative average taken, so that any young man of fair intelligence and with an honest endeavor may finish any of the plates in the time given.

The Course in Lettering, which has also been added to this edition, will be found to be of great practical benefit to students in all kinds of engineering drafting, and will be seen to embrace the most approved practice in drafting room methods at the present time.

The report on the "Present Practice in Drafting Room Methods," which will be found at the end of the book, is also new, and will interest Instructors and enable them to adopt a system in their drawing courses that may closely approximate the best practice in the leading and most progressive drafting rooms in the United States.

The thanks of the author are due and are most cordially extended to those who have used this book in the past and have encouraged and assisted him by gracious words and timely suggestions.

JOHN S. REID.

ARMOUR INSTITUTE OF TECHNOLOGY.
Chicago, Ill., September, 1908.

PREFACE.

In the course of a large experience as an instructor in drawing and designing, the author of this work has often been called upon to teach the elements of mechanical drawing to students in marine, electrical, railway, and mechanical engineering. Having tried and failed to find a book on the subject that was entirely suitable for his use as a text-book, he has found it necessary to prepare the present work.

This course contains, in the author's judgment, a complete and concise statement, accompanied by examples, of the essential principles of mechanical drawing—all that any young man of ordinary intelligence needs to master, by careful study, the more advanced problems met with in machine construction and design. Such works as the author has tried, although most excellent from certain standpoints, were either incomplete in some of the divisions of the subject or too voluminous and elementary in the treatment of details.

The author does not imagine this work is perfect, but he believes that it comes nearer what is needed in teaching the elements of mechanical drawing in technical schools, high schools, evening drawing schools, and colleges than any work he has examined.

The chapter on Conventions will be appreciated by students when called upon to execute working drawings in practical work. The methods described are considered by the author to be those which have met with general approval by the experienced American draftsmen of the present time.

My acknowledgments are due to E. C. Cleaves, professor of drawing, Sibley College, Cornell University, for reading the manuscript and making some valuable suggestions.

THE AUTHOR.

April 1, 1898.

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MECHANICAL DRAWING.

INTRODUCTION.

A NEED has been felt by instructors and students, especially in technical courses, for a text-book that would illustrate the fundamental principles of mechanical drawing in such a practical, lucid, direct and progressive way as to enable the instructor to teach, and the student to acquire, the greatest number of the essential principles involved, and the ability to apply them, in a draftsman-like manner, in the shortest space of time.

With this in mind, the present work has been prepared from the experience of the writer, a practical draftsman and teacher for over fifteen years.

THE COMPLETE OUTFIT.

The outfit for students in mechanical and machine drawing is as follows:

(1) THE DRAWING-BOARD for academy and freshman work is 16″×21″×½″, the same as that used for free-hand drawing. The material should be soft pine and constructed as shown by Fig. 1.

(2) 1 SCRIBBLING PENCIL with rubber tip.

(3) PENCILS, one 6H and one 4H Koh-i-noor or Faber.

(4) The T-SQUARE; a plain pearwood T-square with a fixed head is all that is necessary. Length 21″.

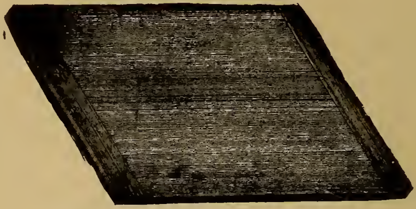


FIG. 1.

(5) INSTRUMENTS. "Pocket Book" Set, shown by Fig. 2, recommended as a first-class medium-priced set of instruments. It contains

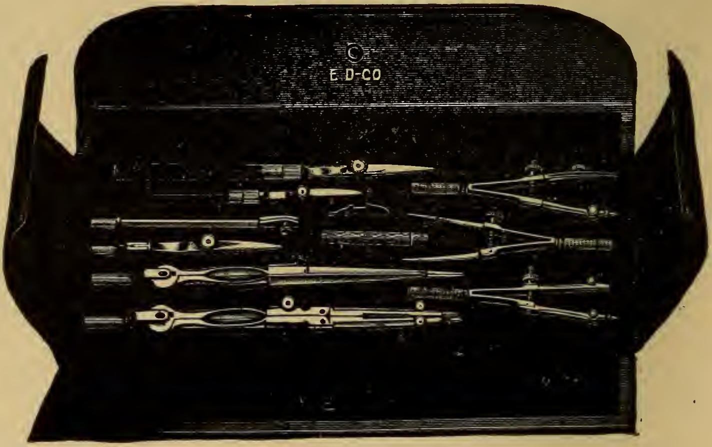


FIG. 2.

A COMPASS, $5\frac{1}{2}''$ long, with fixed needle-point, pencil, pen and lengthening bar; a SPRING BOW PENCIL, 3″ long; a SPRING BOW PEN, 3″ long; a SPRING BOW SPACER, 3″ long;

2 Drawing-pens, medium and small, 1 Hair-spring Divider; 5″ long; a nickel-plated box with leads.

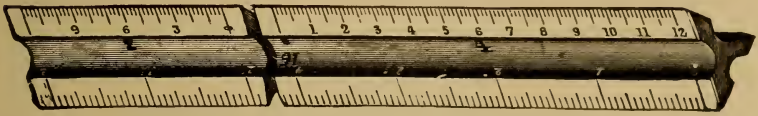
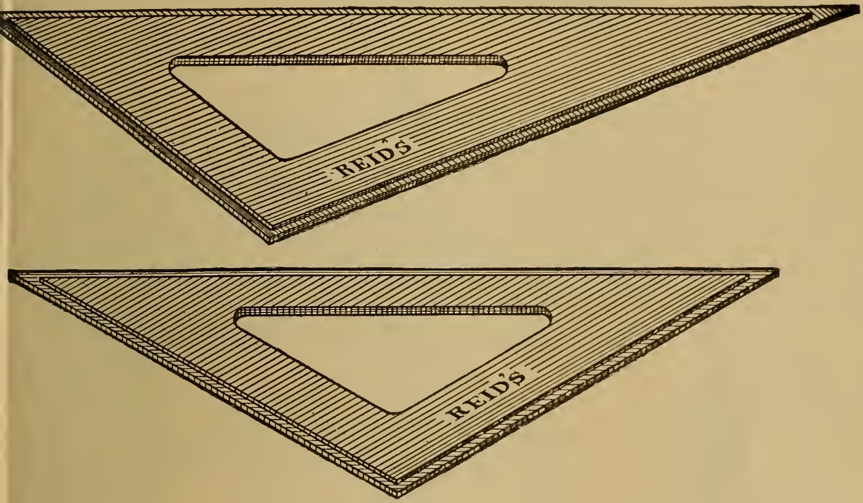

9
6
3
1
2
3
4
5
6
7
8
9
10
11
12

Fig. 3.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REID'S

Fig. 4.

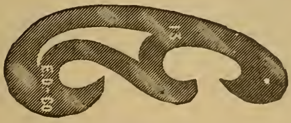


Fig. 5.

(6) A Triangular Boxwood Scale graduated as follows: 4″ and 2″, 3″ and 1½″, 1″ and ½″, ¾″ and ⅝″, $\frac{1}{16}$″ and $\frac{1}{50}$″.

(7) 1 Triangle 30°×60°, celluloid, 10″ long. Fig. 4.
1 " 45°, " 7″ " "

(8) 1 Irregular Curve. No. 13. Fig. 5.

(9) Emery Pencil Pointer.

(10) Ink, black waterproof. Fig. 7.

(11) Ink Eraser, Faber's Typewriter. No. 104.

(12) Pencil Eraser, "Emerald" No. 211. Fig. 9.

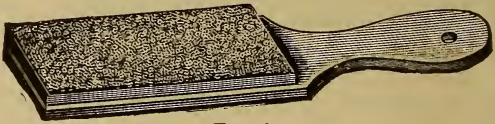


Fig. 6.

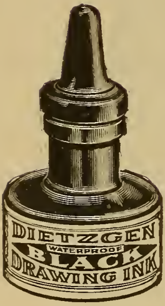

DIETZGEN
WATERPROOF
BLACK
DRAWING INK

Fig. 7.

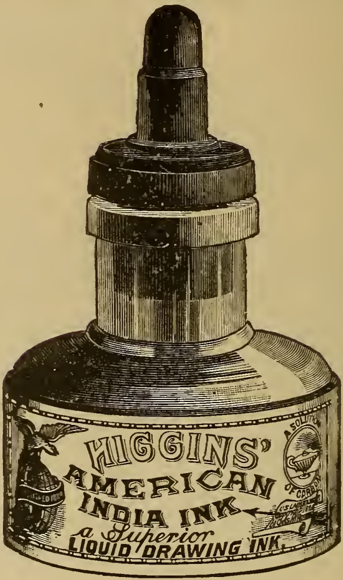

HIGGINS'
AMERICAN
INDIA INK
a Superior
LIQUID DRAWING INK

Fig. 8.

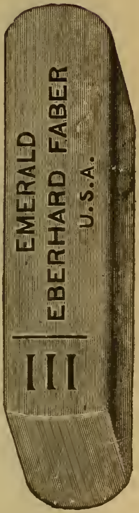

EMERALD
EBERHARD FABER
U.S.A.
III

Fig. 9.

(13) Sponge Rubber or Cube of "Artgum." Figs. 10, 11.

(14) Tacks, a small carton of 1 oz. copper tacks, and 1 doz. small thumb tacks.

(15) Arkansas Oil Stone. $2'' \times \frac{1}{2}'' \times \frac{1}{16}''$.

(16) Protractor, German silver, about 5″ diam. Fig. 12.

(17) Scale Guard, " " Fig. 13.

(18) 2 sheets of "Cream" Drawing Paper. 15″×20″.
(19) 2 " " Imperial Tracing Cloth. 15″×20″.
(20) 1 Cross-section Pad. 8″×10″.
(21) 1 Scribbling Pad.

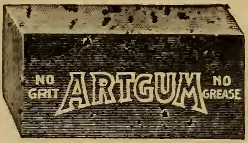

NO GRIT
ARTGUM
NO GREASE

Fig. 10.

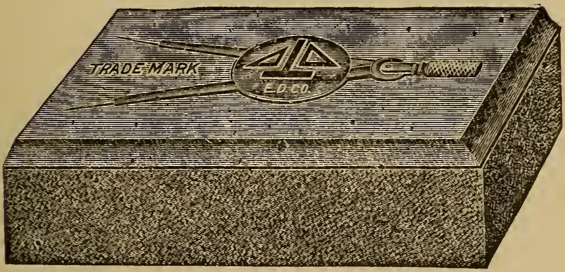

TRADE-MARK
E.D.CO.

Fig. 11.

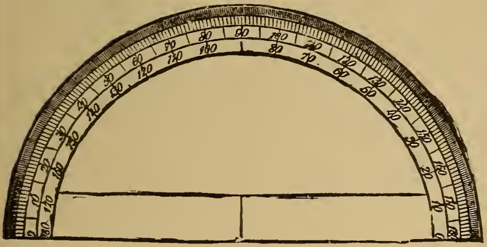


Fig. 12.

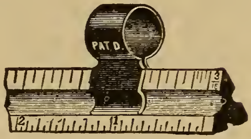


Fig. 13.

(22) 1 Erasing Shield, nickel plated.
(23) 2 Lettering Pens, "Gillott" No. 303.
(24) 2 " " "Ball Point," No. 506.
(25) 2 " " " " No. 516.
(26) 1 Two-foot Rule.

CHAPTER I.

INSTRUMENTS.

It is a common belief among students that any kind of cheap instrument will do with which to learn mechanical drawing, and not until they have acquired the proper use of the instruments should they spend money in buying a first-class set. This is one of the greatest mistakes that can be made. Many a student has been discouraged and disgusted because, try as he would, he could not make a good drawing, using a set of instruments with which it would be difficult for even an experienced draftsman to make a creditable showing.

If it is necessary to economize in this direction it is better and easier to get along with a fewer number, and have them of the best, than it is to have an elaborate outfit of questionable quality.

The instruments shown in Fig. 2 are well made of a moderate price, and with care and attention will give good satisfaction for a long time.

USE OF INSTRUMENTS.

The Pencil.—Designs of all kinds are usually worked out in pencil first, and if to be finished and kept they are inked in and sometimes colored and shaded; but if the drawing is only to be finished in pencil, then all the lines except construction, center, and dimension lines should be made broad and dark, so that the drawing will stand out clear and distinct. It will be noticed that this calls for two kinds of pencil-lines, the first a thin, even line made with a hard, fine-grained lead-pencil, not less than 6H (either Koh-i-noor or Faber's), and sharpened to a knife-edge in the following manner: The lead should be carefully bared of the wood with a knife for about $\frac{1}{2}''$, and the wood neatly tapered back from that point; then lay the lead upon the emery-paper sharpener illustrated in the outfit, and carefully rub to and fro until the pencil assumes a long taper from the wood to the point; now turn it over and do the same with the other side, using toward the last a slightly oscillating motion on both sides until the point has assumed a sharp, thin, knife-edge endwise and an elliptical contour the other way.

This point should then be polished on a piece of scrap drawing-paper until the rough burr left by the emery-paper is removed, leaving a smooth, keen, ideal pencil-point for drawing straight lines.

With such a point but little pressure is required in the hands of the draftsman to draw the most desirable line, one that can be easily erased when necessary and inked in to much better advantage than if the line had been made with a blunt point, because, when the pencil-point is blunt the inclination is to press hard upon it when drawing a line. This forms a groove in the paper which makes it very difficult to draw an even inked line.

The second kind of a pencil-line is the broad line, as explained above; it should be drawn with a somewhat softer pencil, say 4H, and a thicker point.

All lines not necessary to explain the drawing should be erased before inking or broadening the pencil-lines, so as to make a minimum of erasing and cleaning after the drawing is finished.

When drawing pencil-lines, the pencil should be held in a plane passing through the edge of the T-square perpendicular to the plane of the paper and making an angle with the plane of the paper equal to about 60°.

Lines should always be drawn from left to right. A soft conical-pointed pencil should be used for lettering, figuring, and all free-hand work.

The Drawing-pen.—The best form, in the writer's opinion, is that shown in Fig. 14. The spring on the upper blade spreads the blades sufficiently apart to allow for thorough cleaning and sharpening. The hinged blade is therefore unnecessary. The pen should be held in a plane passing through the edge of the T-square at right angles to the plane of the paper, and making an angle with the plane of the paper ranging from 60° to 90°.

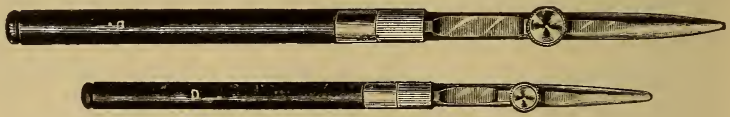


Fig. 14.

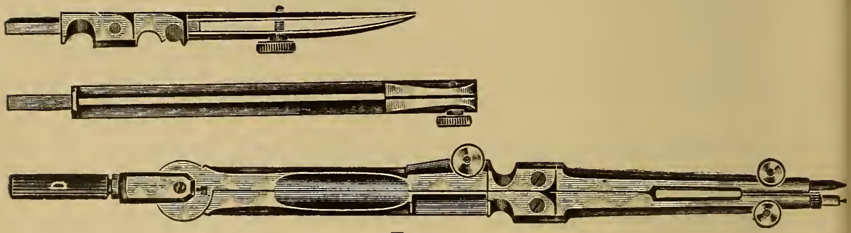


Fig. 15.

The best of drawing-pens will in time wear dull on the point, and until the student has learned from a competent teacher how to sharpen his pens it would be better to have them sharpened by the manufacturer.

It is difficult to explain the method of sharpening a drawing-pen.

If one blade has worn shorter than the other, the blades should be brought together by means of the thumb-screw, and placing the pen in an upright position draw the point to and fro on the oil-stone in a plane perpendicular to it, raising and lowering the handle of the pen at the same time, to give the proper curve to the point. The Arkansas oil-stones (No. 15 of "The Complete Outfit") are best for this purpose.

The blades should next be opened slightly, and holding the pen in the right hand in a nearly horizontal position, place the lower blade on the stone and move it quickly to and fro, slightly turning the pen with the fingers and elevating the handle a little at the end of each stroke. Having ground the lower blade a little, turn the pen completely over and grind the upper blade in a similar manner for about the same length of time; then clean the blades and examine the extreme points, and if there are still bright spots to be seen continue the grinding until they entirely disappear, and finish the sharpening by polishing on a piece of smooth leather.

The blades should not be too sharp, or they will cut the paper. The grinding should be continued only as long as the bright spots show on the points of the blades.

When inking, the pen should be held in about the same position as described for holding the pencil. Many draftsmen hold the pen vertically. The position may be varied with good results as the pen wears. Lines made with the pen should only be drawn from left to right.

THE TRIANGLES.

The triangles shown at Fig. 4 (in "The Complete Outfit") are 10″ and 7″ long respectively, and are made of transparent celluloid. The black rubber triangles sometimes used are but very little cheaper (about 10 cents) and soon become dirty when in use; the rubber is brittle and more easily broken than the celluloid.

Angles of 15°, 75°, 30°, 45°, 60°, and 90° can readily be drawn with the triangles and T-square. Lines parallel to oblique lines on the drawing can be drawn with the triangles by placing the edge representing the height of one of them so as to coincide with the given line, then place the edge representing the hypotenuse of the other against the corresponding edge of the first, and by sliding the upper on the lower when holding the lower firmly with the left hand any number of lines may be drawn parallel to the given line.

The methods of drawing perpendicular lines and making angles with other lines within the scope of the triangles and T-square are so evident that further explanation is unnecessary.

THE T-SQUARE.

The use of the T-square is very simple, and is accomplished by holding the head firmly with the left hand against the left-hand end of the drawing-board, leaving the right hand free to use the pen or pencil in drawing the required lines.

THE DRAWING-BOARD.

If the left-hand edge of the drawing-board is straight and even and the paper is tacked down square with that edge and the T-square, then horizontal lines parallel to the upper edge of the paper and perpendicular to the left-hand edge may be drawn with the T-square, and lines perpendicular to these can be made by means of the triangles, or *set squares*, as they are sometimes called.

THE TRIANGULAR SCALE.

This scale, illustrated in Fig. 3 (in "The Complete Outfit"), was arranged to suit the needs of the students in machine drawing. It is triangular and made of boxwood. The six edges are graduated as follows; $\frac{1}{16}''$ or full size, $\frac{1}{50}''$, $\frac{3}{4}''$ and $\frac{3}{8}'' = 1$ ft., $1''$ and $\frac{1}{2}'' = 1$ ft., $3''$ and $1\frac{1}{2}'' = 1$ ft., and $4''$ and $2'' = 1$ ft.

Drawings of very small objects are generally shown enlarged—e.g., if it is determined to make a drawing twice the full size of an object, then where the object measures one inch the drawing would be made $2''$, etc.

Larger objects or small machine parts are often drawn full size—i.e., the same size as the object really is—and the drawing is said to be made to the scale of full size.

Large machines and large details are usually made to a reduced scale—e.g., if a drawing is to be made to the scale of $2'' = 1$ ft., then $2''$ measured by the standard rule would be divided into 12 equal parts and each part would represent $1''$. See Fig. 81*b*.

THE SCALE GUARD.

This instrument is shown in No. 17 (in "The Complete Outfit"). It is employed to prevent the scale from turning, so that the draftsman can use it without having to look for the particular edge he needs every time he wants to lay off a measurement.

THE COMPASSES.

When about to draw a circle or an arc of a circle, take hold of the compass at the joint with the thumb and two first fingers, guide the needle-point into the center and set the pencil or pen leg to the required radius, then move the thumb and forefinger up to the small handle provided at the top of the instrument, and beginning at the lowest point draw the line clockwise. The weight of the compass will be the only down pressure required.

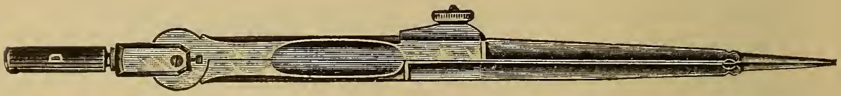


FIG. 16.

The sharpening of the lead for the compasses is a very important matter, and cannot be emphasized too much. Before commencing a drawing it pays well to take time to properly sharpen the pencil and the lead for compasses and to keep them always in good condition.

The directions for sharpening the compass leads are the same as has already been given for the sharpening of the straight-line pencil.

THE DIVIDERS OR SPACERS.

This instrument should be held in the same manner as described for the compass. It is very useful in laying off equal distances on straight lines or circles. To divide a given line into any number of equal parts with the dividers, say 12, it is best to divide the line into three or four parts first, say 4, and then when one of these parts has been subdivided accurately into three equal parts, it will be a simple matter to step off these latter divisions on the remaining three-fourths of the given line. Care should be taken not to make holes in the paper with the spacers, as it is difficult to ink over them without blotting.

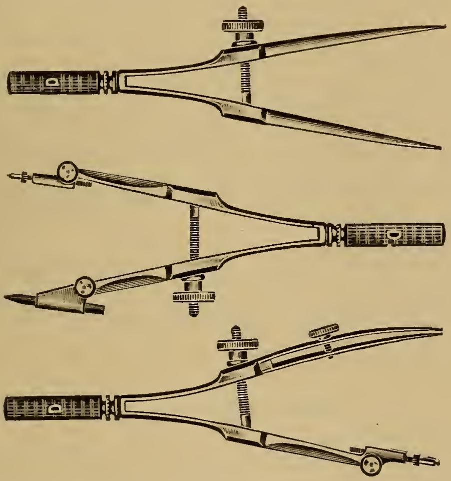


Fig. 17.

THE SPRING BOWS.

These instruments are valuable for drawing the small circles and arcs of circles. It is very important that all the small arcs, such as fillets, round corners, etc., should be carefully pencilled in before beginning to ink a drawing. Many good drawings are spoiled because of the bad joints between small arcs and straight lines.

When commencing to ink a drawing, all small arcs and small circles should be inked first, then the larger arcs and circles, and the straight lines last. This is best, because it is much easier to know where to stop the arc line, and to draw the straight line tangent to it, than *vice versa.*

IRREGULAR CURVES.

The irregular curve shown in Fig. 5 is useful for drawing irregular curves through points that have already been found by construction, such as ellipses, cycloids epicyloids, etc., as in the cases of gear-teeth, cam outlines, rotary pump wheels, etc.

When using these curves, that curve should be selected that will coincide with the greatest number of points on the line required.

THE PROTRACTOR.

This instrument is for measuring and constructing angles. It is shown in Fig. 12. It is used as follows when measuring an angle: Place the lower straight edge on the straight line which forms one of the sides of the angle, with the nick exactly on the point of the angle to be measured. Then the number of degrees contained in the angle may be read from the left, clockwise.

In constructing an angle, place the nick at the point from which it is desired to draw the angle, and on the outer circumference of the protractor, find the figure corresponding to the number of degrees in the required angle, and mark a point on the paper as close as possible to the figure on the protractor; after removing the protractor, draw a line through this point to the nick, which will give the required angle.

CHAPTER II.

GEOMETRICAL DRAWING.

The following problems are given to serve a double purpose: to teach the use of drawing instruments, and to point out those problems in practical geometry that are most useful in mechanical drawing, and to impress them upon the mind of the student so that he may readily apply them in practice.

The drawing-paper for this work should be divided temporarily, with light pencil-lines, into as many squares and rectangles as may be directed by the instructor, and the drawings made as large as the size of the squares will permit. The average size of the squares should be not less than 4″. When a sheet of drawings is finished these boundary lines may be erased.

It will be noticed in the illustrations of this chapter that all construction lines are made very narrow, and given and required lines quite broad. This is sufficient to distinguish them, and employs less time than would be necessary if the construction lines were made broken, as is often the case.

If time will permit, it is advisable to ink in some of these drawings toward the last. In that event, the given lines may be red, the construction lines blue, and the required lines black.

But even when inked in in black, the broad and narrow lines would serve the purpose very well without the use of colored inks.

The principal thing to be aimed at in making these drawings is accuracy of construction. All dimensions should be laid off carefully, correctly, and quickly. Straight lines joining arcs should be exactly tangent, so that the joints cannot be noticed. It is the little things like these that make or mar a drawing, and if attended to or neglected they will make or mar the draftsman. The constant endeavor of the student should be to make every drawing he begins more accurate, quicker and better in every way than the preceding one.

A drawing should never be handed in as finished until the student is perfectly sure that he cannot improve it in any way whatever, for the act of handing in a drawing is the same, or should be the same, as saying This is the best that I can do; I cannot improve it; it is a true measure of my ability to make this drawing.

If these suggestions are faithfully followed throughout this course, success awaits *any one* who earnestly desires it.

Prob. 1. Fig. 18. TO BISECT A FINITE STRAIGHT LINE.—With A and B in turn as centers, and a radius greater than the half of AB, draw arcs intersecting at E and F. Join EF bisecting AB at C.

An arc of a circle may be bisected in the same way.

Prob. 2. Fig. 19. TO ERECT A PERPENDICULAR AT THE END OF THE LINE.—Assume the point E above the line as center and radius EB describe an arc CBD cutting the line AB in the point C. From C draw a line through E cutting the arc in D. Draw DB the perpendicular.

Prob. 3. Fig. 20. THE SAME PROBLEM: A SECOND METHOD.—

With center *B* and any radius as *BC* describe an arc *CDE* with the same radius; measure off the arcs *CD* and *DE*. With *D* and *E* as centers and any convenient radius describe arcs intersecting at *F*. *FB* is the required perpendicular.

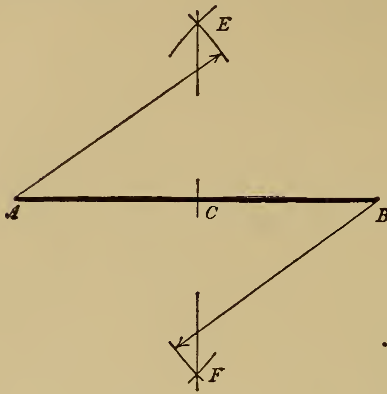


FIG. 18.

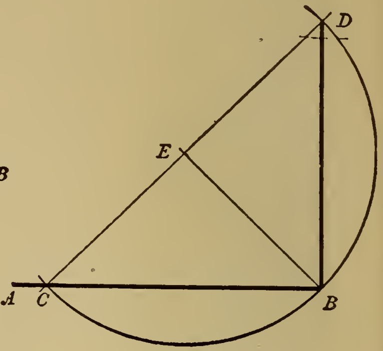


FIG. 19.

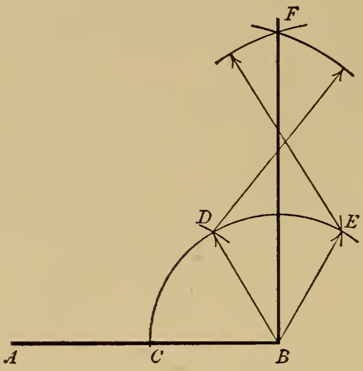


FIG. 20.

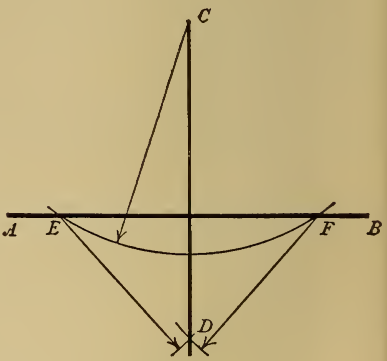


FIG. 21.

Prob. 4. Fig. 21. TO DRAW A PERPENDICULAR TO A LINE FROM A POINT ABOVE OR BELOW IT.—Assume the point *C* above the line. With center *C* and any suitable radius cut the line *AB* in *E* and *F*. From *E* and *F* describe arcs cutting in *D*. Draw *CD* the perpendicular required.

Prob. 5. Fig. 22. TO BISECT A GIVEN ANGLE.—With *A* as center and any convenient radius describe the arc *BC*. With *B* and *C* as centers and any convenient radius draw arcs intersecting at *D*. Join *AD*, then angle *BAD* = angle *DAC*.

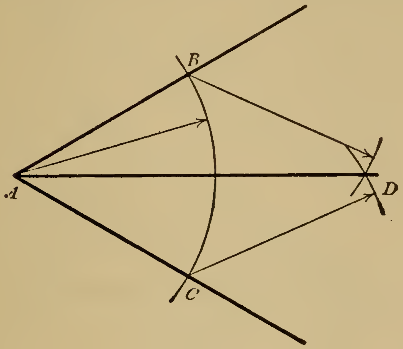


FIG. 22.

Prob. 6. Fig. 23. TO DRAW A LINE PARALLEL TO A GIVEN LINE *AB* THROUGH A GIVEN POINT *C*.—From any point on *AB* as *B* with radius *BC* describe an arc cutting *AB* in *A*. From *C* with the same radius describe arc *BD*. From *B* with *AC* as radius cut arc *BD* in *D*. Draw *CD*. Line *CD* is parallel to *AB*.

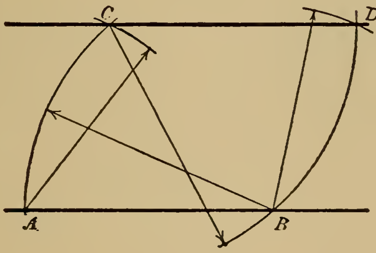


FIG. 23.

Prob. 7. Fig. 24. FROM A POINT *D* ON THE LINE *DE* TO SET OFF AN ANGLE EQUAL TO THE GIVEN ANGLE *BAC*.—From

A with any convenient radius describe arc *BC*. From *D* with the same radius describe arc *EF*. With center *E* and radius *BC* cut arc *EF* in *F*. Join *DF*. Angle *EDF* is = angle *BAC*.

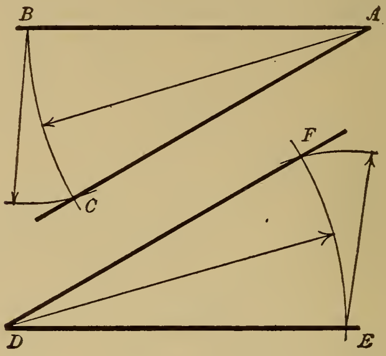


FIG. 24.

Prob. 8. Fig. 25. TO DIVIDE AN ANGLE INTO TWO EQUAL PARTS, WHEN THE LINES DO NOT EXTEND TO A MEETING POINT.—Draw the line *CD* and *CE* parallel and at equal distances from the lines *AB* and *FG*. With *C* as center and any radius draw arcs 1, 2. With 1 and 2 as centers and any con-

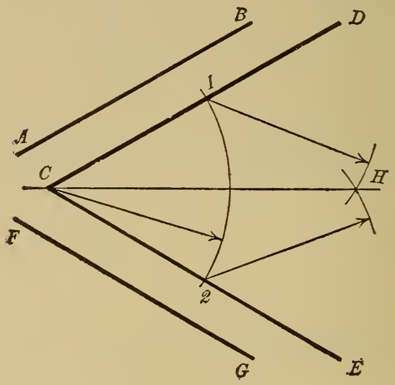


FIG. 25.

venient radius describe arcs intersecting at *H*. A line through *C* and *H* divides the angle into two equal parts.

Prob. 9. Fig. 26. To Construct a Rhomboid having Adjacent Sides equal to two Given Lines *AB* and *AC*, and an Angle equal to a Given Angle *A*.—Draw line *DE* equal to *AB*. Make *D* = angle *A*. Make *DF* = *AC*. From *F* with line *AB* as radius and from *E* with line *AC* as radius describe arcs cutting in *G*. Join *FG* and *EG*.

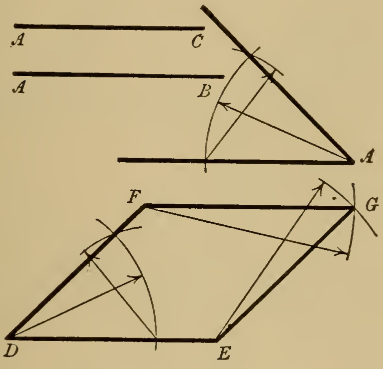


Fig. 26.

Prob. 10. Fig. 27. To Divide the Line *AB* into any Number of equal Parts, say 15.—Draw a line *CD* parallel to *AB*, of any convenient length. From *C* set off along this line the number of equal parts into which the line *AB* is to be divided. Draw *CA* and *DB* and produce them until they intersect at *E*. Through each one of the points 1, 2, 3, 4, etc., draw lines to the point *E*, dividing the line *AB* into the required number of equal parts.

This problem is useful in dividing a line when the point required is difficult to find accurately—e.g., in Fig. 28 *AB* is the *pitch* of the spur gear, partly shown, which includes a space and a tooth and is measured on the *pitch circle.* In cast gears the space is made larger than the thickness of the tooth, the proportion being about 6 to 5—i.e., if we divide the pitch into eleven equal parts the space will measure $\frac{6}{11}$ and the tooth $\frac{5}{11}$. The $\frac{1}{11}$ which the space is larger than the tooth is called the *backlash.* Let *A′B′* be the pitch chord of the arc *AB.* Draw *CD* parallel to *A′B′* at any convenient distance and set off on it 11 equal spaces of any convenient length. Draw *CA′* and *DB′* intersecting at *E.* From point 5 draw a line to *E* which will divide *A′B′* as required; the one part $\frac{5}{11}$ and the other $\frac{6}{11}$.

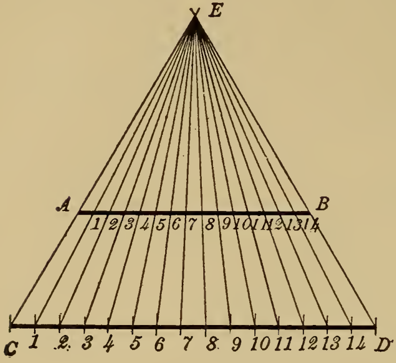


FIG. 27.

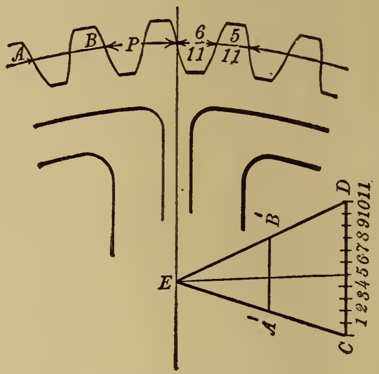
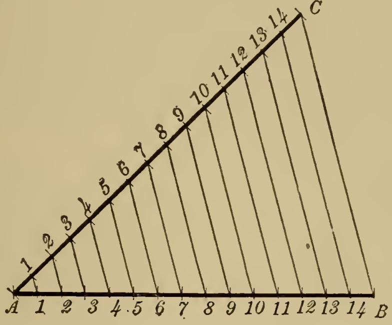


FIG 28.

Prob. 11. Fig. 29. TO DIVIDE A GIVEN LINE INTO ANY NUMBER OF EQUAL PARTS: ANOTHER METHOD.—Let *AB* be the given line. From *A* draw *AC* at any angle, and lay off on it the required number of equal spaces of any convenient length. Join *CB* and through the divisions on *AC* draw lines parallel to *CB*, dividing *AB* as required in the points 1′, 2′, 3′, 4′, etc.

Prob. 12. Fig. 30. TO DIVIDE A LINE *AB* PROPORTIONALLY TO THE DIVIDED LINE *CD*.—Draw *AB* parallel to *CD* at any distance from it. Draw lines through *CA* and *DB* and produce them till they meet at *E*. Draw lines from *E* through the divisions 1, 2, 3, 4, etc., of line *CD*, cutting line *AB* in the points 5, 6, 7, 8, etc. The divisions on *AB* will have the same proportion to the divisions on *CD* that the whole line *AB* has to the whole line *CD*—i.e., the lines will be proportionally divided.


C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
A
1
2
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4
5
6
7
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14
B

FIG. 29.

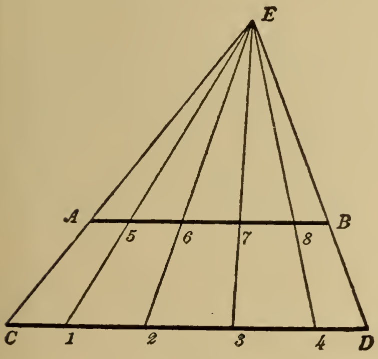

E
A
B
5
6
7
8
C
1
2
3
4
D

FIG. 30.

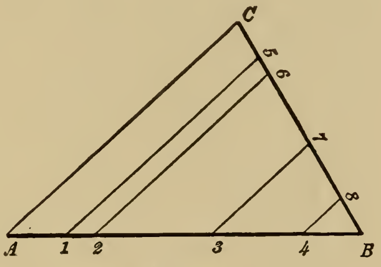

C
5
6
7
8
A
1
2
3
4
B

FIG. 31.

Prob. 13. Fig. 31. THE SAME: ANOTHER METHOD.—Let *BC*, the divided line, make any angle with *BA*, the line to be divided at *B*. Draw line *CA* joining the two ends of the lines. Draw lines from 5, 6, 7, 8, parallel to *CA*, dividing line *AB* in points 1, 2, 3, 4, proportional to *BC*.

Prob. 14. Fig. 32. To Construct an Equilateral Triangle on a Given Base *AB*.—From the points *A* and *B* with *AB* as radius describe arcs cutting in *C*. Draw lines *AC* and *BC*. The triangle *ABC* is equilateral and equiangular.

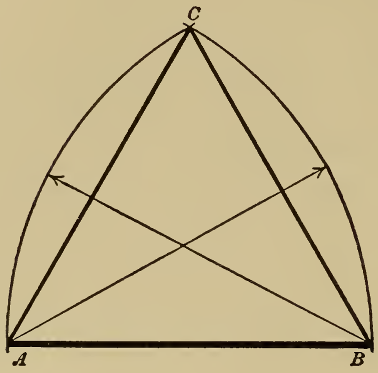


Fig. 32.

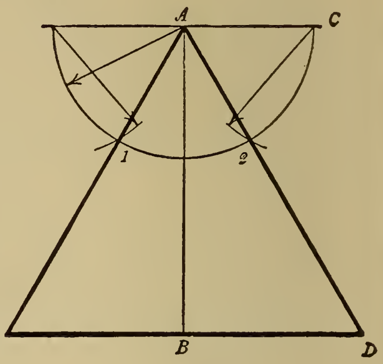


Fig. 33.

Prob. 15. Fig. 33. To Construct an Equilateral Triangle of a Given Altitude, *AB*.—From both ends of *AB* draw lines perpendicular to it as *CA* and *DB*. From *A* with any radius describe a semicircle on *CA* and with its radius cut off arcs 1, 2. Draw lines from *A* through 1, 2, and produce them until they cut the base *BD*.

Prob. 16. Fig. 34. To Trisect a Right Angle *ABC*.— From the angular point *B* with any convenient radius describe an arc cutting the sides of the angle in *C* and *A*. From *C* and *A* with the same radius cut off arcs 1 and 2. Draw lines 1*B* and 2*B*, and the right angle will be trisected.

Prob. 17. Fig. 35. TO CONSTRUCT ANY TRIANGLE, ITS THREE SIDES *AB* AND *C* BEING GIVEN.—From one end of the base as *A* describe an arc with the line *B* as radius. From the other end with line *C* as radius describe an arc, cutting the first arc in *D*. From *D* draw lines to the ends of line *A*, and a triangle will be constructed having its sides equal to the sides given. To construct any triangle the two shorter sides *B* and *C* must together be more than equal to the largest side *A*.

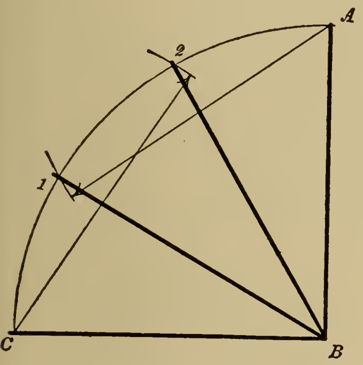


FIG. 34.

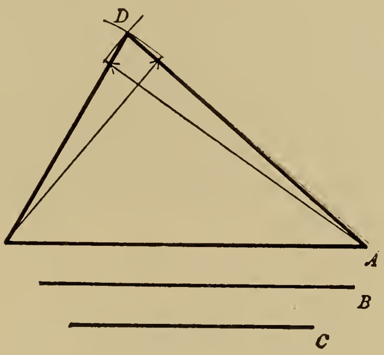


FIG. 35.

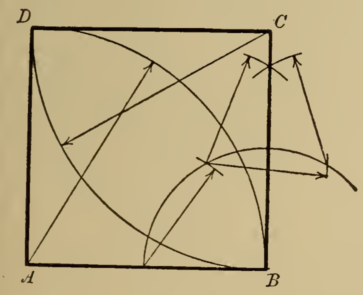


FIG. 36.

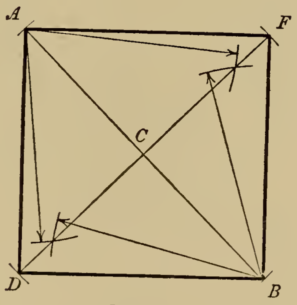


FIG. 37.

Prob. 18. Fig. 36. TO CONSTRUCT A SQUARE, ITS BASE *AB* BEING GIVEN.—Erect a perpendicular at *B*. Make *BC* equal to *AB*. From *A* and *C* with radius *AB* describe arcs cutting in *D*. Join *DC* and *DA*.

Prob. 19. Fig. 37. TO CONSTRUCT A SQUARE, GIVEN ITS DIAGONAL *AB*.—Bisect *AB* in *C*. Draw *DF* perpendicular to *AB* at *C*. Make *CD* and *CF* each equal to *CA*. Join *AD*, *DB*, *BF*, and *FA*.

Prob. 20. Fig. 38. TO CONSTRUCT A REGULAR POLYGON OF ANY NUMBER OF SIDES, THE CIRCUMSCRIBING CIRCLE BEING GIVEN.—At any point of contact, as *C*, draw a tangent *AB* to the given circle. From *C* with any radius describe a semicircle cutting the given circle. Divide the semicircle into as many equal parts as the polygon is required to have sides, as 1, 2, 3, 4, 5, 6. Draw lines from *C* through each division, cutting the circle in points which will give the angles of the polygon.

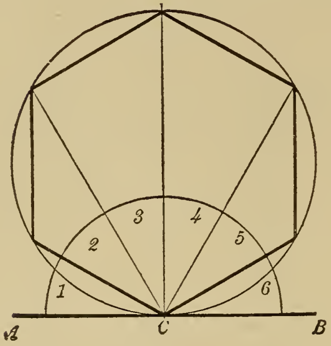


FIG. 38.

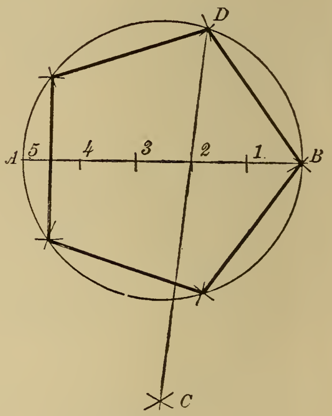


FIG. 39.

Prob. 21. Fig. 39. ANOTHER METHOD.—Draw a diameter *AB* of the given circle. Divide *AB* into as many equal parts as the polygon is to have sides, say 5. From *A* and *B* with the line *AB* as radius describe arcs cutting in *C*, draw a line from *C* through the second division of the diameter and produce it cutting the circle in *D*. *BD* will be the side of the required polygon. The line *C* must always be drawn through the second division of the diameter, whatever the number of sides of the polygon.

Prob. 22. Fig. 40. TO CONSTRUCT ANY REGULAR POLYGON WITH A GIVEN SIDE *AB*.—Make *BD* perpendicular and equal to *AB*. With *B* as center and radius *AB* describe arc *DA*. Divide arc *DA* into as many equal parts as there are sides in the required polygon, as 1, 2, 3, 4, 5. Draw *B*2. Bisect line *AB* and erect a perpendicular at the bisection cutting *B*2 in *C*. With *C* as center and radius *CB* describe a circle. With *AB* as a chord step off the remaining sides of the polygon.

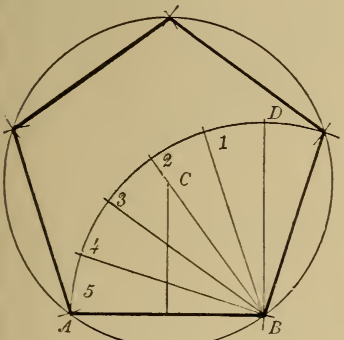


FIG. 40.

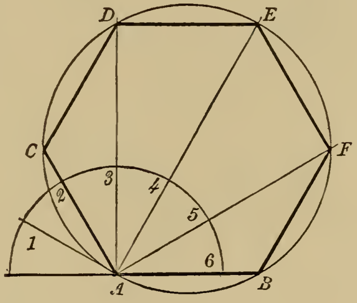


FIG. 41.

Prob. 23. Fig. 41. ANOTHER METHOD.—Extend line *AB*. With center *A* and any convenient radius describe a semicircle. Divide the semicircle into as many equal parts as there are sides in the required polygon, say 6. Draw lines through every division except the first. With *A* as center and *AB* as radius cut off *A*2 in *C*. From *C* with the same radius cut *A*3 in *D*. From *D*, *A*4 in *E*. From *B*, *A*5 in *F*. Join *AC*, *CD*, *DE*, *EF*, and *FB*.

Prob. 24. Fig. 42. To Construct a Regular Heptagon, the Circumscribing Circle being given.—Draw a radius *AB*. With *B* as center and *BA* as radius, cut the circumference in 1, 2; it will be bisected by the radius in *C*. *C*1 or *C*2 is equal to the side of the required heptagon.

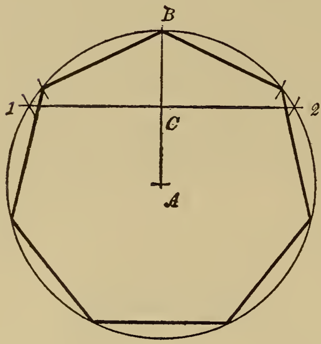


Fig. 42.

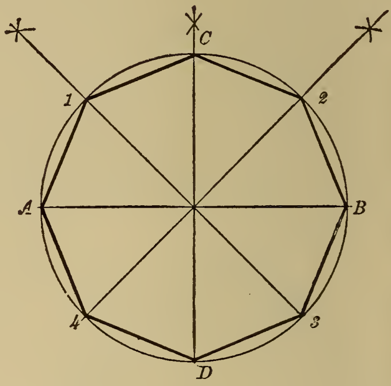


Fig 43.

Prob. 25. Fig. 43. To Construct a Regular Octagon, the Circumscribing Circle being given.—Draw a diameter *AB*. Bisect the arcs *AB* in *C* and *D*. Bisect arcs *CA* and *CB* in 1 and 2. Draw lines from 1 and 2 through the center of the circle, cutting the circumference in 3 and 4. Join *A*1, 1*C*, *C*2, 2*B*, *B*3, etc.

Prob. 26. Fig. 44. To Construct a Pentagon, the Side *AB* being given.—Produce *AB*. With *B* as center and *BA* as radius, describe arc *AD*2. With center *A* and same radius, describe an arc cutting the first arc in *D*. Bisect *AB* in *E*.

Draw line *DE*. Bisect arc *BD* in *F*. Draw line *EF*. With center *C* and radius *EF* cut off arc *C*1 and 1, 2 on the semicircle. Draw line *B*2; it will be a second side of the pentagon. Bisect it and draw a line perpendicular to it at the bisection. The perpendiculars from the sides *AB* and *B*2 will cut in *G*. With *G* as center and radius *GA* describe a circle· it will contain the pentagon.

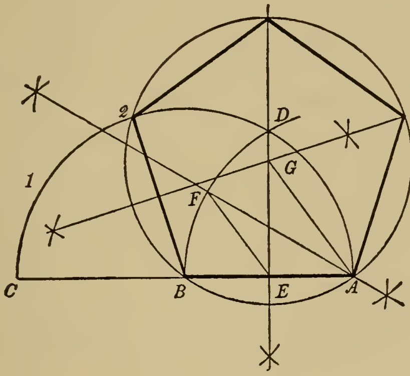


FIG. 44.

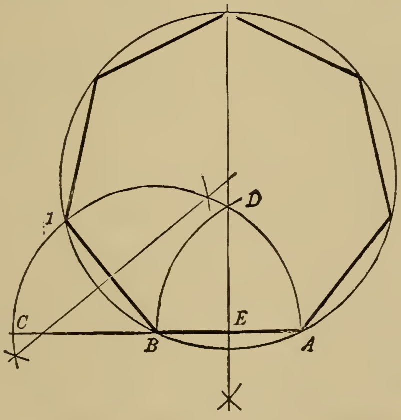


FIG. 45.

Prob. 27. Fig. 45. TO CONSTRUCT A HEPTAGON ON A GIVEN LINE *AB*.—Extend line *AB* to *C*. From *B* with radius *AB* describe a semicircle. With center *A* and same radius describe an arc cutting the semicircle in *D*. Bisect *AB* in *E*. Draw line *DE*. With *C* as center and *DE* as radius, cut off arc 1 on the semicircle. Draw line *B*1; it is a second side of the heptagon. Bisect it and obtain the center of the circumscribing circle as in the preceding problem.

Prob. 28. Fig. 46. TO INSCRIBE AN OCTAGON IN A GIVEN SQUARE.—Draw diagonals *AD*, *CB* intersecting at *O*. From *A*, *B*, *C*, and *D* with radius equal to *AO* describe quadrants cutting the sides of the square in 1, 2, 3, 4, 5, 6, 7, 8. Join these points and the octagon will be inscribed.

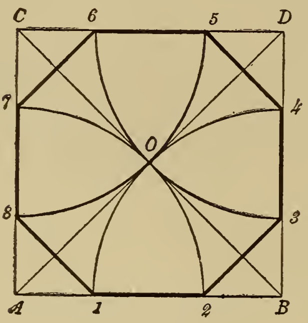


FIG. 46.

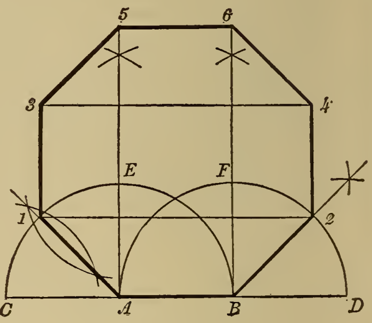


FIG. 47.

Prob. 29. Fig. 47. TO CONSTRUCT A REGULAR OCTAGON ON A GIVEN LINE *AB*.—Extend line *AB* in both directions. Erect perpendiculars at *A* and *B*. With centers *A* and *B* and radius *AB* describe the semicircle *CEB* and *AF*2. Bisect the quadrants *CE* and *DF* in 1 and 2, then *A*1 and *B*2 will be two more sides of the octagon. At 1 and 2 erect perpendiculars 1, 3 and 2, 4 equal to *AB*. Draw 1–2 and 3–4. Make the perpendiculars at *A* and *B* equal to 1–2 or 3–4—viz., *A*5 and *B*6. Complete the octagon by drawing 3–5, 5–6, and 6–4.

Prob. 30. Fig. 48. TO DRAW A RIGHT LINE EQUAL TO HALF THE CIRCUMFERENCE OF A GIVEN CIRCLE.—Draw a diameter *AB*. Draw line *AC* perpendicular to *AB* and equal to three times the radius of the circle. Draw another perpendicular at *B* to *AB*. With center *B* and radius of the circle cut off arc *BD*, bisect it and draw a line from the center of the circle through the bisection, cutting line *B* in *E*. Join *EC*. Line *EC* will be equal to half the circumference of circle *A*.

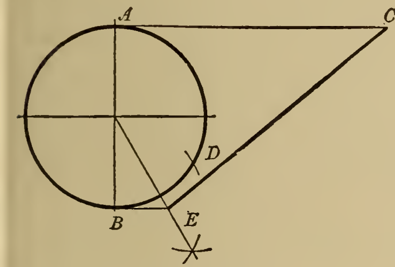


FIG. 48.

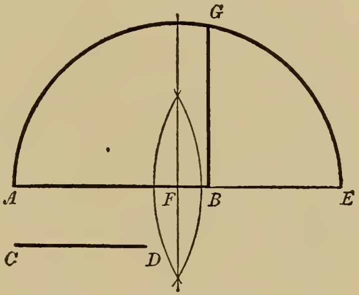


FIG. 49.

Prob. 31. Fig. 49. TO FIND A MEAN PROPORTIONAL TO TWO GIVEN RIGHT LINES.—Extend the line *AB* to *E* making *BE* equal to *CD*. Bisect *AE* in *F*. From *F* with radius *FA* describe a semicircle. At *B* where the two given lines are joined erect a perpendicular to *AE* cutting the semicircle in *G*. *BG* will be a mean proportional to *CD* and *AB*.

Prob. 32. Fig. 50. TO FIND A THIRD PROPORTIONAL (LESS) TO TWO GIVEN RIGHT LINES *AB* AND *CD*.—Make *EF* = the given line *AB*. Draw *EG* = *DC* making an angle with *EF*. Join *FG*. From *E* with *EG* as radius cut *EF* in *H*. Draw

H parallel to *FG*, cutting *EG* in *I*. *EI* is the third proportional (less) to the two given lines.

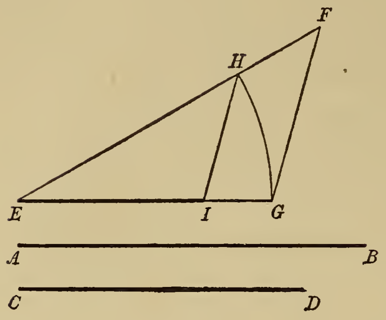


FIG. 50.

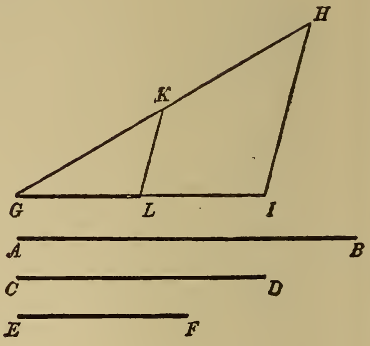


FIG. 51.

Prob. 33. Fig. 51. TO FIND A FOURTH PROPORTIONAL TO THREE GIVEN RIGHT LINES *AB*, *CD*, AND *EF*.—Make *GH* = the given line *AB*. Draw *GI* = *CD*, making any convenient angle to *GH*. Join *HI*. From *G* lay off *GK* = *EF*. From *K* draw a parallel to *HI* cutting *GI* in *L*. *GL* is the fourth proportional required.

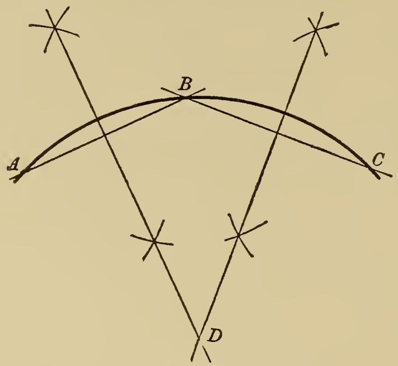


FIG. 52.

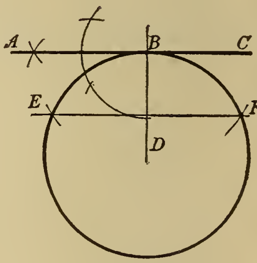


FIG. 53.

Prob. 34. Fig. 52. TO FIND THE CENTER OF A GIVEN ARC *ABC*. —Draw the chords *AB* and *CD* and bisect them. Extend the bisection lines to intersect in *D* the center required.

Prob. 35. Fig. 53. TO DRAW A LINE TANGENT TO AN ARC OF A CIRCLE.—(1st.) When the center is not accessible. Let *B* be the point through which the tangent is to be drawn. From *B* lay off equal distances as *BE*, *BF*. Join *EF* and through *B* draw *ABC* parallel to *EF*. (2d.) When the center *D* is given. Draw *BD* and through *B* draw *ABC* perpendicular to *BD*. *ABC* is tangent to the circle at the point *B*.

Prob. 36. Fig. 54. TO DRAW TANGENTS TO THE CIRCLE *C* FROM THE POINT *A* WITHOUT IT.—Draw *AC* and bisect it in *E*. From *E* with radius *EC* describe an arc cutting circle *C* in *B* and *D*. Join *CB*, *CD*. Draw *AB* and *AD* tangent to the circle *C*.

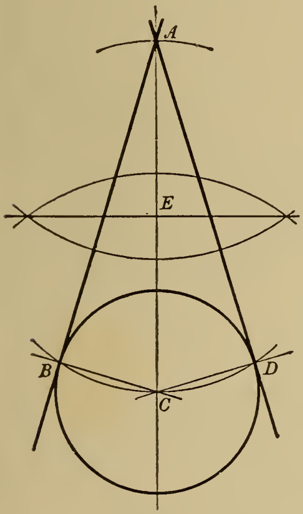


FIG. 54.

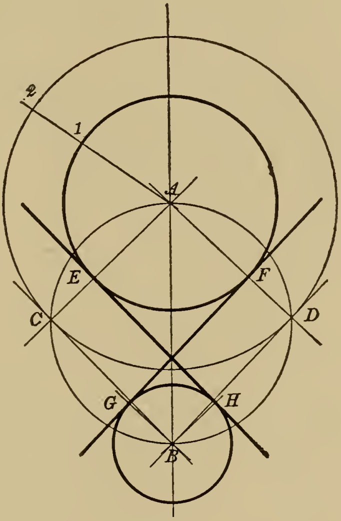


FIG. 55.

Prob. 37. Fig. 55. TO DRAW A TANGENT BETWEEN TWO CIRCLES.—Join the centers *A* and *B*. Draw any radial line from *A* as *A*2 and make 1–2 = the radius of circle *B*. From *A* with radius *A*–2 describe a circle *C*2*D*. From center *B* draw tangents *BC* and *BD* to circle *C*2*D* at the points *C* and *D* by preceding problem. Join *AC* and *AD* and through the points *E* and *F* draw parallels *FG* and *EH* to *BD* and *BC*. *FG* and *EH* are the tangents required.

Prob. 38. Fig. 56. To Draw Tangents to two Given Circles *A* and *B*.—Join *A* and *B*. From *A* with a radius equal to the difference of the radii of the given circles describe a circle *GF*. From *B* draw the tangents *BF* and *BG*, by Prob. 37. Draw *AF* and *AG* extended to *E* and *H*. Through *E* and *H* draw *EC* and *HD* parallel to *BF* and *BG* respectively. *EC* and *DH* are the tangents required.

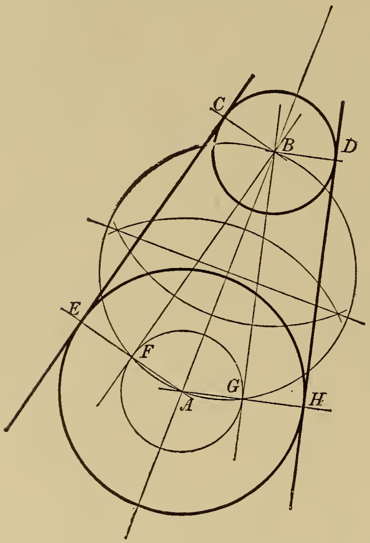


Fig. 56.

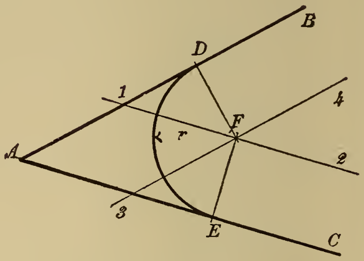


Fig. 57.

Prob. 39. Fig. 57. To Draw an Arc of a Circle of Given Radius Tangent to two Straight Lines.—*AB* and *AC* are the two straight lines, and *r* the given radius. At a distance = *r* draw parallels 1–2 and 3–4 to *AC* and *AB*, intersecting at *F*. From *F* draw perpendiculars *FD* and *FE*. With *F* as center and *FD* or *FE* as radius describe the required arc, which will be tangent to the two straight lines at the points *D* and *E*.

Prob. 40. Fig. 58. To Draw an Arc of a Circle Tangent to two Straight Lines *BC* and *CD* when the Mid-position *G* is given.—Draw *CA* the bisection of the angle *BCD* and *EF* at right angles to it through the given point *G*. Next bisect either of the angles *FEB* or *EFD*. The bisection line will intersect the central line *CA* at *A*, which will be the center of the arc. From *A* draw perpendiculars *A*1 and *A*2, and with either as a radius and *A* as center describe an arc which will be tangent to the lines *BC* and *CD* at the points 1 and 2.

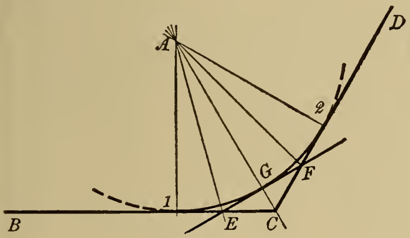


Fig. 58.

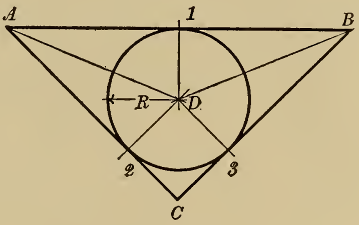


Fig. 59.

Prob. 41. Fig. 59. To Inscribe a Circle within a Triangle *ABC*.—Bisect the angles *A* and *B*. The bisectors will meet in *D*. Draw *D*1 perpendicular to *AB*. Then with center *D* and radius = *D*1 describe a circle which will be tangent to the given triangle at the points 1, 2, 3.

Prob. 42. Fig. 60. To Draw an Arc of a Circle of Given Radius *R* tangent to two Given Circles *A* and *B*.—From *A* and *B* draw any radial lines as *A*3, *B*4. Outside the circumference of each circle cut off distances 1–3 and 2–4 each = the given radius *R*. Then with center *A* and radius *A*–3, and center *B* and radius *B*–4 describe arcs intersecting at *C*. Draw *CA*, *CB* cutting the circles at 5 and 6. With centre *C* and radius *C*5 or *C*6 describe an arc which will be tangent at points 5 and 6.

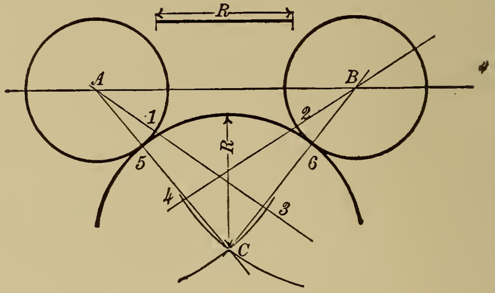


FIG. 60.

Prob. 43. Fig. 61. To Draw an Arc of a Circle of Given Radius *R* tangent to two Given Circles *A* and *B* when the Arc includes the Circles.—Through *A* and *B* draw convenient diameters and extend them indefinitely. On

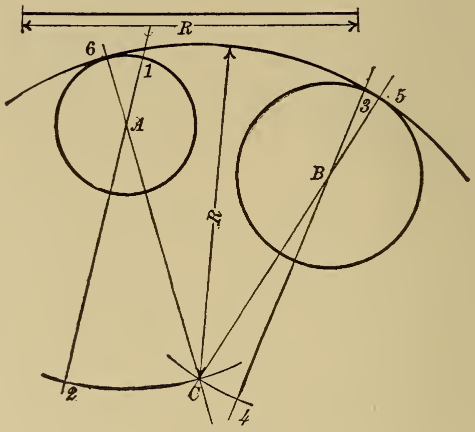


FIG. 61.

these measure off the distances 1–2 and 3–4, each equal in length to the given radius *R*. Then with center *A* and radius *A*2, center *B* and radius *B*4, describe arcs cutting at *C*. From *C* draw *C*5 and *C*6 through *B* and *A*. With center *C* and radius *C*6 or *C*5 describe the arc 6, 5, which will be tangent to the circles at the points 6 and 5.

Prob. 44. Fig. 62. To Draw an Arc of a Circle of Given Radius *R* tangent to Two Given Circles *A* and *B* when the Arc includes one Circle and excludes the other.—Through *A* draw any diameter and make 1–2 = *R*.

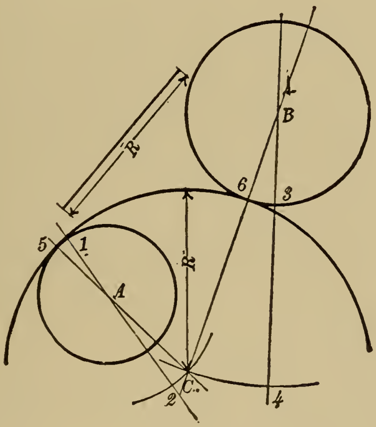


Fig. 62.

From *B* draw any radius and extend it, making 3–4 = *R*. With center *A* and radius *A*2 and center *B* and radius *B*4 describe arcs cutting at *C*. With *C* as center and radius = *C*5 or *C*6 describe the arc 5, 6.

Prob. 45. Fig. 63. Draw an Arc of a Circle of Given Radius *R* tangent to a Straight Line *AB* and a Circle *CD*.—From *E*, the center of the given circle, draw an arc of a circle 1, 2 concentric with *CD* at a distance *R* from it, and also a straight line 3, 4 parallel to *AB* at the same distance *R* from *AB*. Draw *EO* intersecting *CD* at 5. Draw the perpendicular *O*6. With center *O* and radius *O*6 or *O*5 describe the required arc.

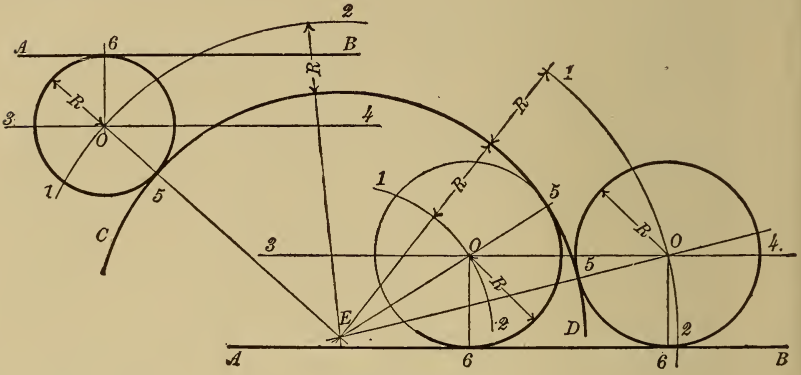

A
6
B
2
R
3
R
O
4
1
5
C
1
R
R
5
3
O
R
E
2
D
A
6
1
R
O
4.
5
2
6
B

FIG. 63.

Prob. 46. Fig. 64. TO DESCRIBE AN ELLIPSE APPROXIMATELY BY MEANS OF THREE RADII (F. R. Honey's method).—

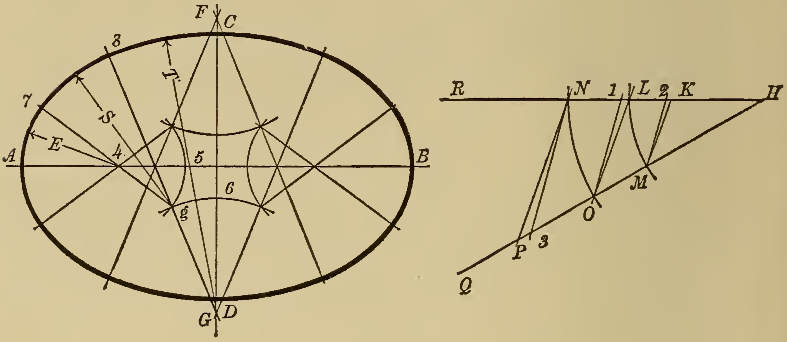

F
C
8
T
7
S
A
E
4
5
B
6
9
G
D
R
N
1
L
2
K
H
M
O
P
3
Q

FIG. 64.

Draw straight lines *RH* and *HQ*, making any convenient angle at *H*. With center *H* and radii equal to the semi-minor and semi-major axes respectively, describe arcs *LM* and *NO*. Join *LO* and draw *MK* and *NP* parallel to *LO*. Lay off *L*1 = $\frac{1}{8}$ of *LN*. Join *O*1 and draw *M*2 and *N*3 parallel to *O*1. Take *H*3 for the longest radius (= *T*), *H*2 for the shortest radius (= *E*), and one-half the sum of the semi-axes for the third radius (= *S*), and use these radii to describe the ellipse as follows: Let *AB* and *CD* be the major and minor axes. Lay off *A*4 = *E* and *A*5 = *S*. Then lay off *CG* = *T* and *C*6 = *S*. With *G* as center and *G*6 as radius draw the arc 6, *g*. With center 4 and radius 4, 5, draw arc 5, *g*, intersecting 6, *g* at *g*. Draw the line *Gg* and produce it making *G*8 = *T*. Draw *g*, 4 and extend it to 7 making *g*, 7 = *S*. With center *G* and radius *GC* (= *T*) draw the arc *C*8. With center *g* and radius *g*, 8 (= *S*) draw the arc 8, 7. With center 4 and radius 4, 7 (= *E*) draw arc 7*A*. The remaining quadrants can be drawn in the same way.

Prob. 47. Fig. 65. TO DRAW AN ELLIPSE HAVING GIVEN THE AXES *AB* AND *CD*.—Draw *AB* and *CD* at right angles to and bisecting each other at *E*. With center *C* and radius *EA* cut *AB* in *F* and *F'* the foci. Divide *EF* or *EF'* into a number of parts as shown at 1, 2, 3, 4, etc. Then with *F* and *F'* as centers and *A*1 and *B*1, and *A*2 and *B*2, etc., as radii describe arcs intersecting in *R*, *S*, etc., until a sufficient number of points

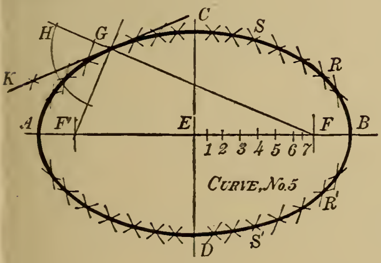


FIG. 65.

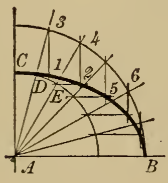


FIG. 66.

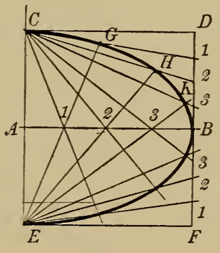


FIG. 67.

are found to draw the elliptic curve accurately throughout. (No. 5 of the "Sibley College Set" of irregular curves is very useful in drawing this curve.) To draw a tangent to the ellipse at the point *G*: Extend *FG* and draw the bisector of the angle *HGF'*. *KG* is the tangent required.

Prob. 48. Fig. 66. ANOTHER METHOD.—Let *AB* and *AC* be the semi axes. With *A* as center and radii *AB* and *AC* describe circles. Draw any radii as *A*3 and *A*4, etc. Make 3 1, 4 2, etc., perpendicular to *AB*, and *D*2, *E*5, etc., parallel to *AB*. Then 1, 2, 5, etc., are points on the curve.

Prob. 49. Fig. 67. ANOTHER METHOD.—Place the diameters as before, and construct the rectangle *CDEF*. Divide *AB* and *DB* and *BF* into the same number of equal parts as 1, 2, 3 and *B*. Draw from *C* through points 1, 2, 3 on *AB* and *BD* lines to meet others drawn from *E* through points 1, 2, 3 on *AB* and *FB* intersecting in points *GHK*. *GHK* are points on the curve.

Prob. 50. Fig. 68. ANOTHER METHOD.—Place the diameters *AB* and *CD* as shown in Drawing No. 1. Draw any convenient angle *RHQ*, Drawing No. 2. With center *H* and radii equal to the semi-minor and semi-major axes describe arcs *LM* and

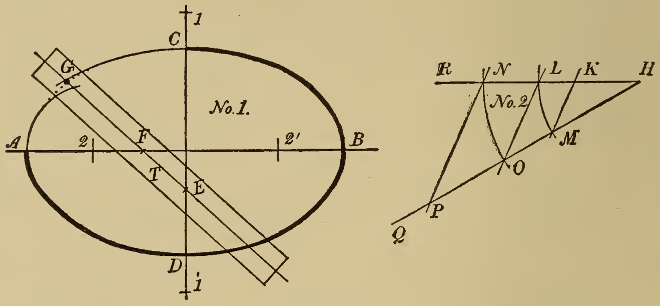


FIG. 68.

NO. Join *LO* and draw *MK* and *NP* parallel to *LO*. Then from *C* and *D* with a distance = *HP* lay off the points 1 1′ on the minor axis and from *A* and *B* with a distance = *HK* lay off the points 2 2′ on the major axis. With centers 1, 1′, 2 and 2′ and radii 1–*D* and 2′–*B*, respectively, draw arcs of circles. On a piece of transparent celluloid *T* lay off from the point *G*, *GF* and *GE* = the semi-minor and semi-major axes respectively. Place the point *F* on the major axis and the point *E* on the minor axis. If the strip of celluloid is now moved over the figure, so that the point *E* is always in contact with the semi-minor axis and the point *F* with the semi major axis, the necessary number of points may be marked through a small hole in the celluloid at *G* with a sharp conical-pointed pencil, and thus complete the curve of the ellipse between the arcs of circles.

Prob. 51. Fig. 69. TO CONSTRUCT A PARABOLA, THE BASE *CD* AND THE ABSCISSA *AB* BEING GIVEN.— Draw *EF* through *A* parallel to *CD* and *CE* and *DF* parallel to *AB*. Divide *AE*, *AF*, *EC*, and *FD* into the same number of equal parts. Through the points 1, 2, 3 on *AF* and *AE* draw lines parallel to *AB*, and through *A* draw lines to the points 1, 2, 3 on *FD* and *EC* intersecting the parallel lines in points 4, 5, 6, etc., of the curve.

Prob. 52. Fig. 70. GIVEN THE DIRECTRIX *BD* AND THE FOCUS *C* TO DRAW A PARABOLA AND A TANGENT TO IT AT THE POINT 3.—The parabola is a curve such that every point in the curve is equally distant from the directrix *BD* and the focus *C*. The vertix *E* is equally distant from the directrix and the focus, i.e. *CE* is = *EB*. Any line parallel to the axis is a diameter. A straight line drawn across the figure at right angles to the axis is a double ordinate, and either half of it is an ordinate. The distance from *C* to any point upon the curve, as 2 is always equal to the horizontal distance from that point to the directrix. Thus $C1 = 1, 1'$, $C2$ to $2, 2'$, etc. Through *C* draw *ACF* at right angles to *BD*, *ACF* is the axis of the curve. Draw parallels to *BD* through any points in *AB*, and with center *C* and radii equal to the horizontal distances of these parallels from *BD* describe arcs cutting in the points 1, 2, 3, 4, etc. These are points in the curve. The tangent to the curve at the point 3 may be drawn as follows: Produce *AB* to *F*. Make *EF* = the horizontal distance of ordinate 33 from *E*. Draw the tangent through 3*F*.

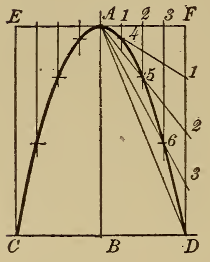


FIG. 69.

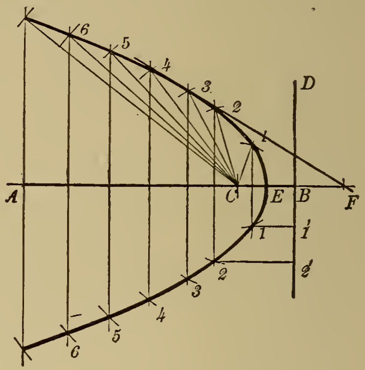


FIG. 70.

Prob. 53. Fig. 71. TO DRAW AN HYPERBOLA, HAVING GIVEN THE DIAMETER *AB*, THE ABSCISSA *BD*, AND DOUBLE ORDINATE *EF*.—Make *F*4 parallel and equal to *BD*. Divide *DF* and *F*4 into the same number of equal parts. From *B* draw lines to the points in 4*F* and from *A* draw lines to the points in *DF*. Draw the curve through the points where the lines correspondingly numbered intersect each other.

Prob. 54. Fig. 72. TO CONSTRUCT AN OVAL THE WIDTH *AB* BEING GIVEN.—Bisect *AB* by the line *CD* in the point *E*, and with *E* as center and radius *EA* draw a circle cutting *CD* in *F*. From *A* and *B* draw lines through *F*. From *A* and *B* with radius equal to *AB* draw arcs cutting the last two lines in *G* and *H*. From *F* with radius *FG* describe the arc *GH* to meet the arcs *AG* and *BH*, which will complete the oval.

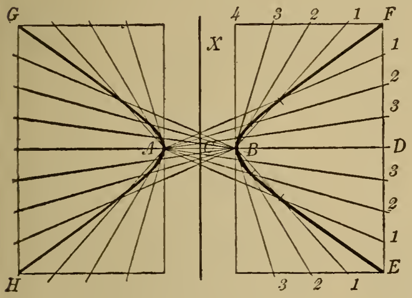


FIG. 71.

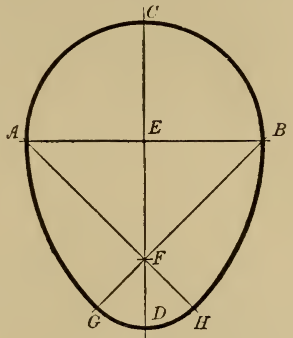


FIG. 72.

Prob. 55. Fig. 73. GIVEN AN ELLIPSE TO FIND THE AXES AND FOCI.—Draw two parallel chords *AB* and *CD*. Bisect each of these in *E* and *F*. Draw *EF* touching the ellipse in 1 and 2. This line divides the ellipse obliquely into equal parts. Bisect 1, 2 in *G*, which will be the center of the ellipse. From *G* with any radius draw a circle cutting the ellipse in *HIJK*. Join these four points and a rectangle will be formed in the ellipse. Lines *LM* and *NO*, bisecting the sides of the rectangle, will be the diameters or axes of the ellipse. With *N* or *O* as centers and radius = *GL* the semi-major axis, describe arcs cutting the major axis in *P* and *Q* the foci.

Prob. 56. Fig. 74. TO CONSTRUCT A SPIRAL OF ONE REVOLUTION.—Describe a circle using the widest limit of the spiral as a radius. Divide the circle into any number of equal parts as *A*, *B*, *C*, etc. Divide the radius into the same number of equal parts as 1 to 12. From the center with radius 12, 1 describe an arc cutting the radial line *B* in 1′. From the center continue to draw arcs from points 2, 3, 4, etc., cutting the corresponding radii *C*, *D*, *E*, etc. in the points 2′, 3′, 4′, etc. From 12 trace the Archimedes Spiral of one revolution.

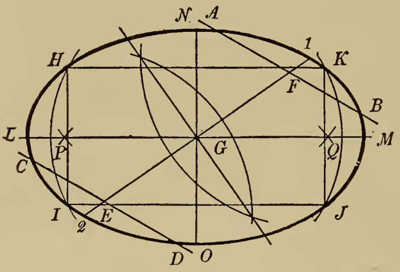


FIG. 73.

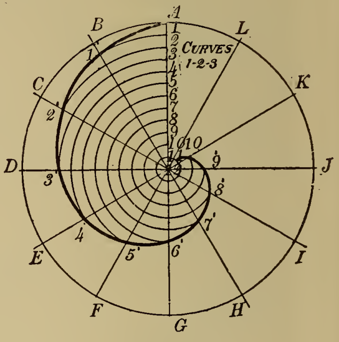


FIG. 74.

Prob. 57. Fig. 75. TO DESCRIBE A SPIRAL OF ANY NUMBER OF REVOLUTIONS, E.G., 2.—Divide the circle into any number of equal parts as *A*, *B*, *C*, etc., and draw radii. Divide the radius *A*12 into a number of equal parts corresponding with the required number of revolutions and divide these into the same number of equal parts as there are radii, viz., 1 to 12. It will be evident that the figure consists of two separate spirals, one from the center of the circle to 12, and one from 12 to *A*. Commence as in the last problem, drawing arcs from 1, 2, 3, etc., to the correspondingly numbered radii, thus obtaining the points marked 1′, 2′, 3′, etc. The first revolution completed, proceed in the same manner to find the points 1″, 2″, 3″, etc. Through these points trace the spiral of two revolutions.

Prob. 58. Fig. 76. TO CONSTRUCT THE INVOLUTE OF THE CIRCLE *O*.—Divide the circle into any number of equal parts and draw radii. Draw tangents at right angles to these radii. On the tangent to radius 1 lay off a distance equal to one of the parts into which the circle is divided, and on each of the tangents set off the number of parts corresponding to the number of the radii. Tangent 12 will then be the circumference of the circle unrolled, and the curve drawn through the extremities of the other tangents will be the involute.

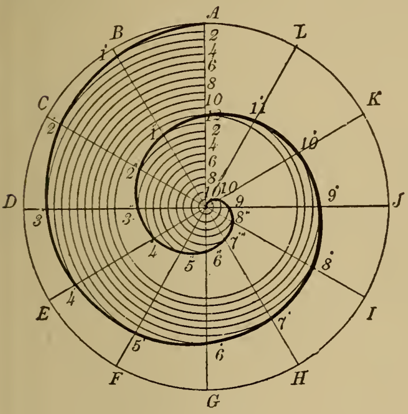


FIG. 75.

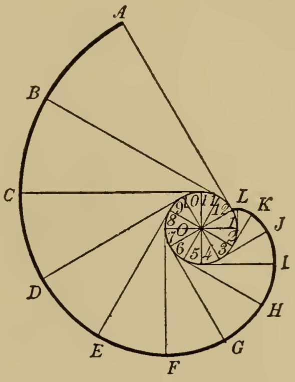


FIG. 76.

Prob. 59. Fig. 77. TO DESCRIBE AN IONIC VOLUTE.—Divide the given height into seven equal parts, and through the point 3 the upper extremity of the third division draw 3, 3 perpendicular to *AB*. From any convenient point on 33 as a center, with radius equal to one-half of one of the divisions on *AB*, describe the eye of the volute *NPNM*, shown enlarged at Drawing No. 2. *NN* corresponds to line 3, 3, Drawing No. 1. Make *PM* perpendicular to *NN* and inscribe the square *NPNM*, bisect its sides and draw the square 11, 12, 13, 14. Draw the diagonals 11, 13 and 12, 14 and divide them as shown in Drawing No. 2. At the intersections of the horizontal with the perpendicular full lines locate the points 1, 2, 3, 4, etc., which will be the centers of the quadrants of the outer curve. The centers for the inner curve will be found at the intersections of the horizontal and perpendicular broken lines, drawn through the divisions on the diagonals. Then with center 1 and radius 1*P* draw arc *PN*, and with center 2 and radius 2*N* draw arc *NM*, with center 3 and radius 3*M* draw arc *ML*, etc. The inner curve is drawn in a similar way, by using the points on the diagonals indicated by the broken lines as centers.

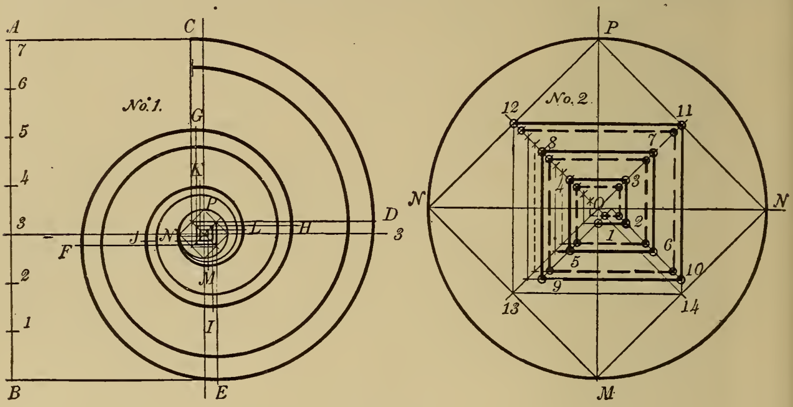


FIG. 77.

Prob. 60. Fig. 78. TO DESCRIBE THE CYCLOID.—*AB* is the director, *CB* the generating circle, *X* a piece of thin transparent celluloid, with one side dull on which to draw the circle *C*. At any point on the circle *C* puncture a small hole with a sharp needle, and place the point *C* tangent to the director *AB* at the point from which the curve is to be drawn. Hold the celluloid at this point with a needle, and rotate it until the arc of the circle *C* intersects the director *AB*. Through the point of intersection stick another needle and rotate *X* until the circle is again tangent to *AB*, and through the puncture at *C* with a 4H pencil, sharpened to a fine conical point, mark the first point on the curve. So proceed until sufficient points have been found to complete the curve.

(Note.—The thin celluloid was first used as a drawing instrument by Professor H. D. Williams, of Sibley College, Cornell University.)

Prob. 61. Fig. 79. To Find the Length of a Given Arc of a Circle approximately.—Let *BC* be the given arc. Draw its chord and produce it to *A*, making *BA* equal half the chord. With center *A* and radius *AC* describe arc *CD* cutting the tangent line *BD* at *D*, and making it equal to the arc *BC*.

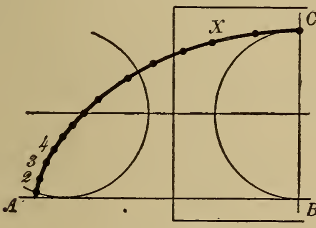


Fig. 78.

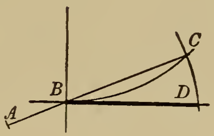


Fig. 79.

Prob. 62. Fig. 80. To Describe the Cycloid by the Old Method.—Divide the director and the generating circle into the same number of equal parts. Through the center *a* draw *ag* parallel to *AB* for the line of centers, and divide it as *AB* in the points *b*, *c*, *d*, *e*, *f*, and *g*. With centers *f*, *e*, *d*, etc., describe arcs tangent to *AB*, and through the points of division on the generating circle 1, 2, 3, etc., draw lines parallel to

AB cutting the arcs in the points 1′, 2′, 3′, etc. These will be points in the curve.

An approximate curve may be drawn by arcs of circles. Thus, taking *f′* as center and *f′g′* as radius, draw arc *g′*1′.

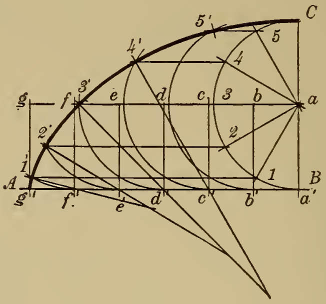


FIG. 80.

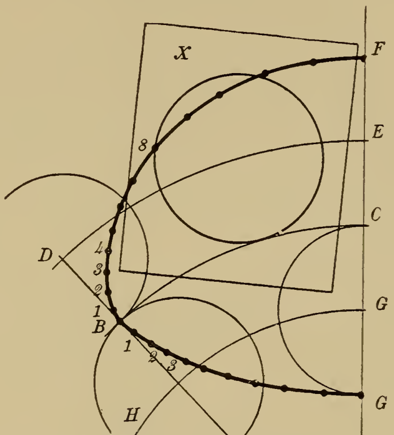
Produce 1′*f′* and 2′*e′* until they meet at the center of the second arc 2′*f′*, etc.

Prob. 63. Fig. 81. TO DESCRIBE THE EPICYCLOID AND THE HYPOCYCLOID.—Divide the generating circle into any number of equal parts, 1, 2, 3, etc., and set off these lengths from *C* on the directing circle *CB* as *e′*, *d′*, *c′*, etc. From *A* the center of the directing circle draw lines through *e′*, *d′*, *c′*, etc., cutting the circles of centers in *e*, *d*, *c*, etc. From each of these points as centers describe arcs tangent to the directing circle. From center *A* draw arcs through the points of division on the generating circle, cutting the arcs of the generating circles in their several positions at the points 1′, 2′, 3′, etc. These will be points in the curve.

Prob. 64. Fig. 82. ANOTHER METHOD.—Draw the generating circle on the celluloid and roll it on the outside of the generating circle *BC* for the Epicycloid, and on the inside for the

Hypocycloid, marking the points in the curve 1, 2, 3, etc., in similar manner to that described for the Cycloid.

FIG. 82.


X
F
E
C
G
G
D
B
H
8
4
3
2
1
1
2
3

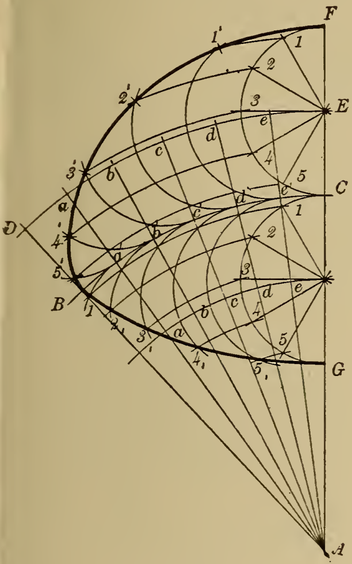

F
E
C
G
A
D
B
1
2
3
4
5
a
b
c
d
e

FIG. 81.

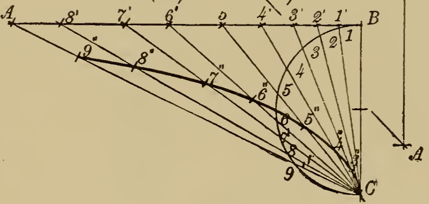

A
B
C
A
8'
7'
6'
5'
4'
3'
2'
1'
1
2
3
4
5
6
7
8
9

FIG. 83.

Prob. 65. Fig. 83. TO DRAW THE CISSOID.—Draw any line *AB* and *BC* perpendicular to it. On *BC* describe a circle. From the extremity *C* of the diameter draw any number of lines, at any distance apart, passing through the circle and meeting the line *AB* in 1′, 2′, 3′, etc. Take the length from *A* to 9 and set it off from *C* on the same line to 9″. Take the distance from 8′ to 8 and set it off from *C* on the same line to 8″, etc., for the other divisions, and through 9″, 8″, 7″, 6″, etc., draw the curve.

Prob. 66. Fig. 84. TO DRAW SCHIELE'S ANTI-FRICTION CURVE. —Let *AB* be the radius of the shaft and *B*1, 2, 3, 4, etc., its axis. Set off the radius *AB* on the straight edge of a piece of stiff paper or thin celluloid and placing the point *B* on the division 1 of the axis, draw through point *A* the line *A*1. Then lower the straight edge until the point *B* coincides with 2 and the point *A* just touches the last line drawn, and draw *a*2, and so proceed to find the points *a*, *b*, *c*, etc. Through these points draw the curve.

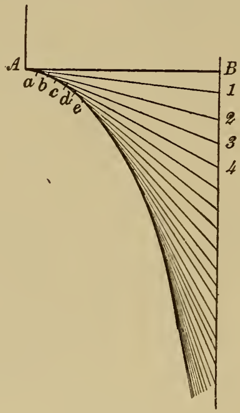


FIG. 84.

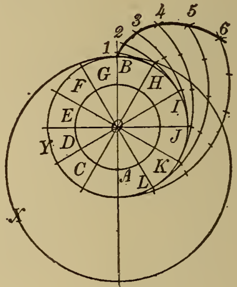


FIG. 85.

Prob. 67. Fig. 85. TO DESCRIBE AN INTERIOR EPICYCLOID.— Let the large circle *X* be the generator and the small circle *Y* the director. Divide circle *Y* into any number of equal parts, as *B*, *H*, *I*, *J*, etc. Draw radial lines and make *HC*, *ID*, *JE*, *KF*, etc., each equal to the radius of the generator *X*. With centers *C*, *D*, *E*, etc., describe arcs tangent at *H*, *I*, *J*, etc. Make *H*1 equal to one of the divisions of the director as *BH*. Make *I*2 equal to two divisions, *J*3, three divisions, etc., and draw the curve through the points 1, 2, 3, 4, etc. This curve may also be described with a piece of celluloid in a similar way to that explained for the cycloid.

It may not be out of place here to describe a few of the

MOULDINGS USED IN ARCHITECTURAL WORK,

since they are often found applied to mechanical constructions.

Prob. 68. Fig. 86. To Describe the "Scotia."—1, 1 is the top line and 4, 4 the bottom line. From 1 drop a perpendicular 1, 4; divide this into three equal parts, as 1, 2, and 3. Through the point 2 draw *ab* parallel to 1, 1. With center 2 and radius 2, 1 describe the semicircle *a*1*b*, and with center *b* and radius *ba* describe the arc *a*5 tangent to 4, 4 at 5, draw the fillets 1, 1 and 4, 4.

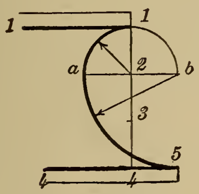


Fig. 86.

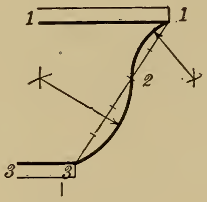


Fig. 87.

Prob. 69. Fig. 87. To Describe the "Cyma Recta."—Join 1, 3 and divide it into five equal parts, bisect 1, 2 and 2, 3, and with radius equal to 1, 2 and 2, 3 respectively describe arcs 1, 2 and 2, 3. Draw the fillets 1, 1 and 3, 3 and complete the moulding.

Prob. 70. Fig. 88. To Describe the "Cavetto" or "Hollow."—Divide the perpendicular 1, 2 into three equal parts and make 2, 3 equal to two of these. From centers 1 and 3 with a radius somewhat greater than the half of 1, 3, describe arcs intersecting at the center of the arc 1, 3,

Prob. 71. Fig. 89. TO DESCRIBE THE "ECHINUS," "QUARTER ROUND," OR "OVOLO."—Draw 1, 2 perpendicular to 2, 3, and divide it into three equal parts. Make 2, 3 equal to two of these parts. From the points 2 and 3 with a radius greater than half 1, 3, describe arcs cutting in the center of the required curve.

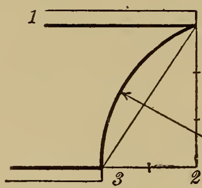


FIG. 88.

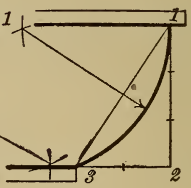


FIG 89.

Prob. 72. Fig. 90. TO DESCRIBE THE "APOPHYGEE."—Divide 3, 4 into four equal parts and lay off five of these parts from 3 to 2. From points 2 and 4 as centers and radius equal to 2, 3, describe arcs intersecting in the center of the curve.

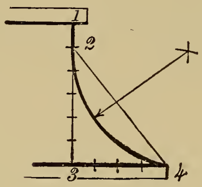


FIG. 90.

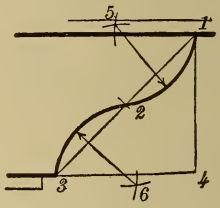


FIG. 91.

Prob. 73. Fig. 91. TO DESCRIBE THE "CYMA REVERSA."—Make 4, 3 = 4, 1. Join 1, 3 and bisect it in the point 2. From the points 1, 2 and 3 as centers and radii equal to about two-thirds of 1, 2 draw arcs intersecting at 5 and 6. Points 5 and 6 are the centers of the reverse curves.

Prob. 74. Fig. 92. TO DESCRIBE THE "TORUS."—Let 1, 2 be the breadth. Drop the perpendicular 1, 2, and bisect it in the point 3. With 3 as center and radius 3, 1, describe the semicircle. Draw the fillets.

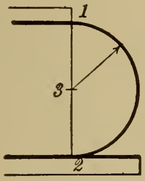


FIG. 92.

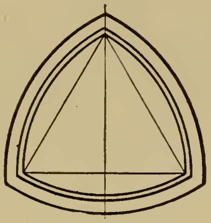


FIG. 93.

Prob. 75. Fig. 93. AN ARCHED WINDOW OPENING.—The curves are all arcs of circles, drawn from the three points of the equilateral triangle, as shown in the figure.

Prob. 76. Fig. 94. TO DESCRIBE THE "TREFOIL."—The equilateral triangle is drawn first, and the angle 1, 2, 3 bisected by the line 2, 4, which also cuts the perpendicnlar line 1, 6 in the point 6. The center of the surrounding circles 1, 2 and 3 are the centers of the trefoil curves.

Prob. 77. Fig. 95. TO DESCRIBE THE "QUATRE FOIL."—Draw the square 1, 2, 3, 4 in the position shown in the figure. The center of the surrounding circles, point 5, is at the intersection of the diagonals of the square. Points 1, 2, 3, 4 of the square are the centers of the small arcs.

Prob. 78. Fig. 96. TO DESCRIBE THE "CINQUEFOIL ORNAMENT." The curves of the cinquefoil are described from the corners of a pentagon 1, 2, 3, 4, 5. Bisect 4, 5 in 6 and draw 2, 6, cutting the perpendicular in the point 7, the center of the large circles.

Prob. 79. Fig. 97. TO DRAW A BALUSTER.—Begin by drawing the center line, and lay off the extreme perpendicular height, the intermediate, perpendicular, and horizontal dimensions, and finally the curves as shown in the figure.

FIG. 94.

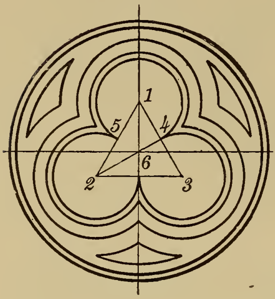


FIG. 95.

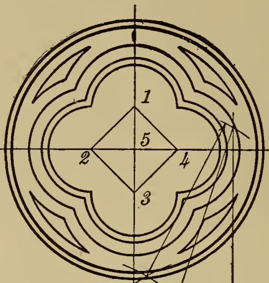
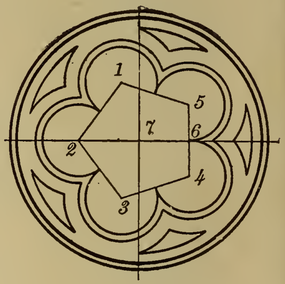


FIG. 96.



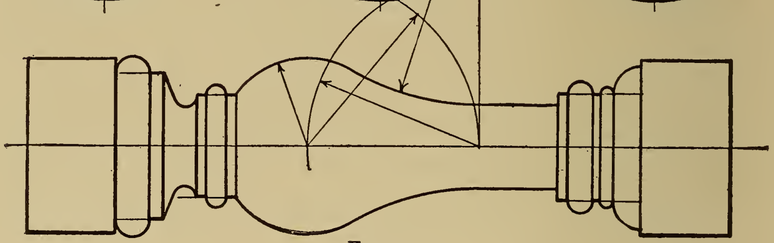


FIG. 97.

DRAWING TO SCALE.

When we speak of a drawing as having been made to scale, we mean that every part of it has been drawn proportionately and accurately, either *full size*, *reduced* or *enlarged*.

Very small and complicated details of machinery are usually drawn enlarged; larger details and small machines may be made full size, while larger machines and large details are shown reduced.

When a drawing of a machine is made to a reduced or enlarged scale the figures placed upon it should always give the full-size dimensions, i.e., the sizes the machine should measure when finished.

Prob. 80. Fig. 98. TO CONSTRUCT A SCALE OF THIRD SIZE OR 4″= 1 FOOT.—Draw upon a piece of tough white drawing-paper two parallel lines about 1″ apart and about 14″ long as shown by *a*, Fig. 98. From *A* lay off distances equal to 4″ and divide the first space *AB* into 12 equal parts or inches by Prob. 12. Divide *AE* in the same way into as many parts as it may be desired to subdivide the inch divisions on *AB*, usually 8. When the divisions and subdivisions have been carefully and lightly drawn in pencil, as shown by *a*, in Fig. 98, then the lines denoting $\frac{1}{8}''$, $\frac{1}{4}''$, $\frac{1}{2}''$, 1″, and 3″ should be carefully inked and numbered as shown by (*b*). By a further subdivision a scale of 2″= 1 foot may easily be made as shown by (*c*) in Fig. 98.

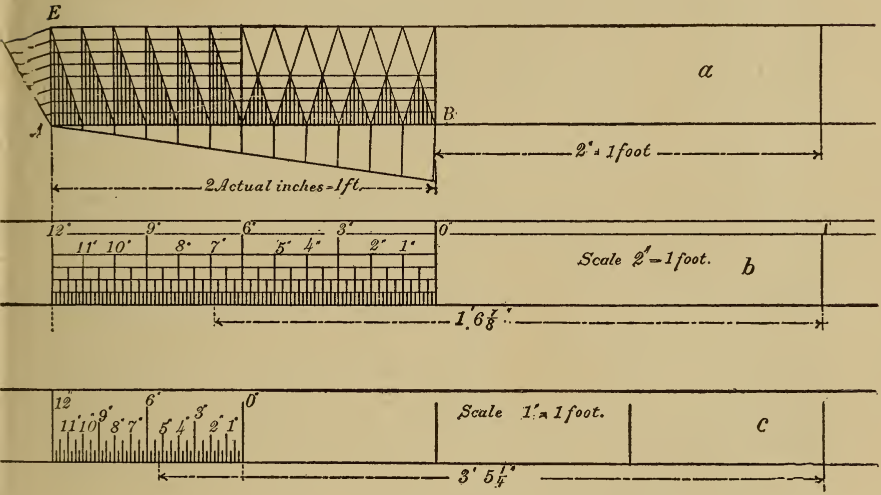

E
a
B
A
2" = 1foot
2 Actual inches = 1ft.
12" 9" 6" 3" 0"
11" 10" 8" 7" 5" 4" 2" 1"
Scale 2"=1 foot.
b
1' 6 7/8"
12 9 6 3 0
11 10 8 7 5 4 2 1
Scale 1"=1 foot.
c
3' 5 1/4"

FIG. 98.

CHAPTER III.

CONVENTIONS.

It is often unnecessary if not undesirable to represent certain things as they would actually appear in a drawing, especially when much time and labor is required to make them orthographically true.

So for economic reasons draftsmen have agreed upon conventional methods to represent many things that would otherwise entail much extra labor and expense, and serve no particular purpose.

It is very necessary, however, that all draftsmen should *know how* to draw these things correctly, for occasions will often arise when such knowledge will be demanded; and besides it gives one a feeling of greater satisfaction when using conventional methods to know that he could make them artistically true if it was deemed necessary.

STANDARD CONVENTIONAL SECTION LINES.

Conventional section lines are placed on drawings to distinguish the different kinds of materials used when such drawings are to be finished in pencil, or traced for blue printing, or to be used for a reproduction of any kind.

Water-colors are nearly always used for finished drawings and sometimes for tracings and pencil drawings.

The color tints can be applied in much less time than it takes to hatch-line a drawing. So that the color method should be used whenever possible.

FIG. 99.—This figure shows a collection of hatch-lined sections that is now the almost universal practice among draftsmen in this and other countries, and may be considered standard.

No. 1. To the right is shown a section of a wall made of *rocks*. When used without color, as in tracing for printing, the rocks are simply shaded with India ink and a 175 Gillott steel pen. For a colored drawing the ground work is made of gamboge or burnt umber. To the left is the conventional representation of water for tracings. For colored drawings a blended wash of Prussian blue is added.

No. 2. *Convention for Marble.*—When colored, the whole section is made thoroughly wet and each stone is then streaked with Payne's gray.

No. 3. *Convention for Chestnut.*—When colored, a ground wash of gamboge with a little crimson lake and burnt umber is used. The colors for graining should be mixed in a separate dish, burnt umber with a little Payne's gray and crimson lake added in equal quantities and made dark enough to form a sufficient contrast to the ground color.

No. 4. *General Convention for Wood.*—When colored the ground work should be made with a light wash of burnt sienna. The graining should be done with a writing-pen and a dark mixture of burnt sienna and a modicum of India ink.

No. 5. *Convention for Black Walnut.*—A mixture of Payne's gray, burnt umber and crimson lake in equal quantities is used for the ground color. The same mixture is used for graining when made dark by adding more burnt umber.

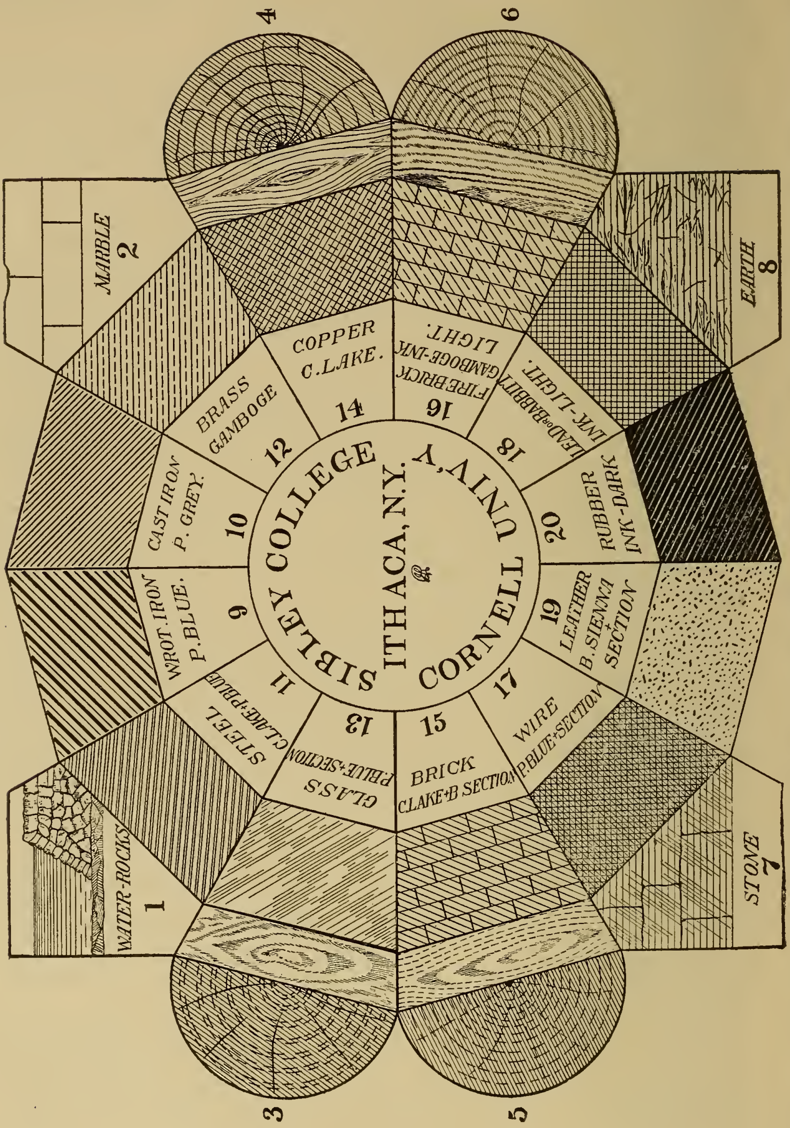

SIBLEY COLLEGE
& CORNELL UNIV'Y
ITHACA, N.Y.
1 WATER-ROCKS
2 MARBLE
3
4
5
6
7 STONE
8 EARTH
9 WROT. IRON P. BLUE.
10 CAST IRON P. GREY.
11 STEEL C.LAKE+P.BLUE
12 BRASS GAMBOGE
13 GLASS P.BLUE+SECTION
14 COPPER C.LAKE.
15 BRICK C.LAKE+B SECTION
16 FIREBRICK GAMBOGE-INK LIGHT.
17 WIRE P.BLUE+SECTION
18 LEAD & BABBIT INK-LIGHT.
19 LEATHER B.SIENNA + SECTION
20 RUBBER INK-DARK

FIG. 99.

No. 6. *Convention for Hard Pine.*—For the ground color make a light wash of crimson lake, burnt umber, and gamboge, equal parts. For graining use a darker mixture of of crimson lake and burnt umber.

No. 7. *Convention for Building-stone.*—The ground color is a light wash of Payne's gray and the shade lines are added mechanically with the drawing-pen or free-hand with the writing-pen.

No. 8. *Convention for Earth.*—Ground color, India ink and neutral tint. The irregular lines to be added with a writing-pen and India ink.

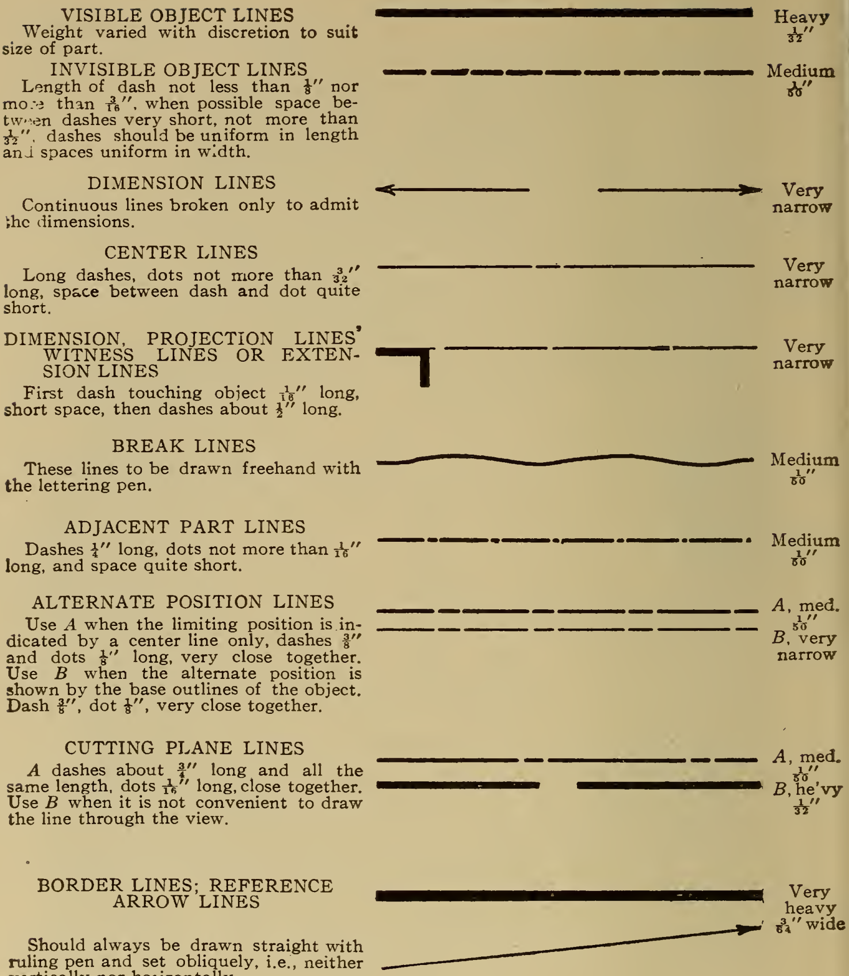
No. 9. *Section Lining for Wrought or Malleable Iron.*—When the drawing is to be tinted, the color used is Prussian blue.

No. 10. *Cast Iron.*—These section lines should be drawn equidistant, not very far apart and narrower than the body lines of the drawing. The tint is Payne's gray.

No. 11. *Steel.*—This section is used for all kinds of steel. The lines should be of the same width as those used for cast-iron and the spaces between the double and single lines should be uniform. The color tint is Prussian blue with enough crimson lake added to make a warm purple.

No. 12. *Brass.*—This section is generally used for all kinds of composition brass, such as gun-metal, yellow metal, bronze metal, Muntz metal, etc. The width of the full lines, dash lines and spaces should all be uniform. The color tint is a light wash of gamboge.

Nos. 13–20.—The section lines and color tints for these numbers are so plainly given in the figure that further instruction would seem to be superfluous.



VISIBLE OBJECT LINES

Weight varied with discretion to suit size of part.

INVISIBLE OBJECT LINES

Length of dash not less than $\frac{1}{8}''$ nor more than $\frac{3}{16}''$, when possible space between dashes very short, not more than $\frac{1}{32}''$, dashes should be uniform in length and spaces uniform in width.

DIMENSION LINES

Continuous lines broken only to admit the dimensions.

CENTER LINES

Long dashes, dots not more than $\frac{3}{32}''$ long, space between dash and dot quite short.

DIMENSION, PROJECTION LINES' WITNESS LINES OR EXTENSION LINES

First dash touching object $\frac{1}{16}''$ long, short space, then dashes about $\frac{1}{2}''$ long.

BREAK LINES

These lines to be drawn freehand with the lettering pen.

ADJACENT PART LINES

Dashes $\frac{1}{4}''$ long, dots not more than $\frac{1}{16}''$ long, and space quite short.

ALTERNATE POSITION LINES

Use *A* when the limiting position is indicated by a center line only, dashes $\frac{3}{8}''$ and dots $\frac{1}{8}''$ long, very close together. Use *B* when the alternate position is shown by the base outlines of the object. Dash $\frac{3}{8}''$, dot $\frac{1}{8}''$, very close together.

CUTTING PLANE LINES

A dashes about $\frac{3}{4}''$ long and all the same length, dots $\frac{1}{16}''$ long, close together. Use *B* when it is not convenient to draw the line through the view.

BORDER LINES; REFERENCE ARROW LINES

Should always be drawn straight with ruling pen and set obliquely, i.e., neither vertically nor horizontally.

Heavy $\frac{1}{32}''$
Medium $\frac{1}{50}''$
Very narrow
Very narrow
Very narrow
Medium $\frac{1}{50}''$
Medium $\frac{1}{50}''$
A, med. $\frac{1}{50}''$ *B*, very narrow
A, med. $\frac{1}{50}''$ *B*, he'vy $\frac{1}{32}''$
Very heavy $\frac{3}{64}''$ wide

FIG. 100.

CONVENTIONAL LINES.

Fig. 100.—There are four kinds:

(1) *The Hidden Line.*—This line should be made of short dashes of uniform length and width, both depending somewhta on the size of the drawing. The width should always

be slightly less than the body lines of the drawing, and the length of the dash should never exceed $\frac{1}{8}''$. The spaces between the dashes should all be uniform, quite small, never exceeding $\frac{1}{16}''$. This line is always inked in with *black ink.*

(2) *The Line of Motion.*—This line is used to indicate *point paths*. The dashes should be made shorter than those of the *hidden line*, just a trifle longer than dots. The spaces should of course be short and uniform.

(3) *Center Lines.*—Most drawings of machines and parts of machines are symmetrical about their center lines. When penciling a drawing these lines may be drawn continuous and as fine as possible, but on drawings for reproductions the black-inked line should be a long narrow dash and two short ones alternately. When colored inks are used the center line should be made a continuous *red* line and as fine as it is possible to make it.

(4) *Dimension Lines and Line of Section.*—These lines are made in *black* with a fine long dash and one short dash alternately. In color they should be continuous *blue* lines. Colored lines should be used wherever feasible, because they are so quickly drawn and when made fine they give the drawing a much neater appearance than when the conventional black lines are used. Colored lines should *never* be broken.

CONVENTIONAL BREAKS.

FIG. 101.—Breaks are used in drawings sometimes to indicate that the thing is actually longer than it is drawn, sometimes to show the shape of the cross-section and the kind of material. Those given in Fig. 101 show the usual practice.

CROSS-SECTIONS.

FIG. 102.—When a cross-section of a pulley, gear-wheel or other similar object is required and the cutting-plane passes through one of the spokes or arms, then only the rim and hub should be sectioned, as shown at *xx* No. 1 and *z* No. 2, and the arm or spoke simply outlined. Cross-sections of the arms may be made as shown at *AA* No. 2. In working drawings of gear-wheels only the number of teeth included in one quadrant need be drawn; the balance is usually shown by conventional lines, e.g., the *pitch* line the same as a center line, viz., a long dash and two very short ones alternately or a fine continuous *red* line.

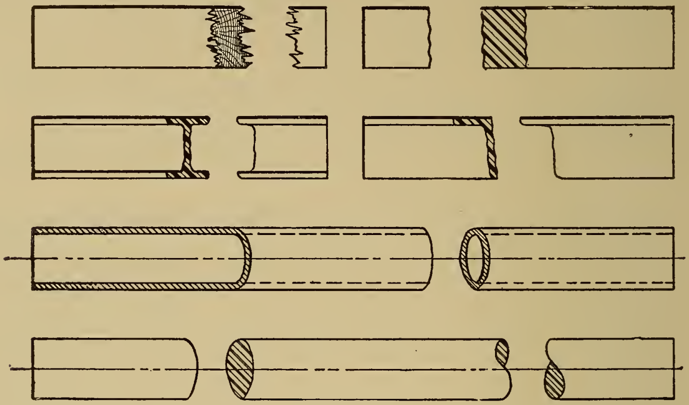


FIG. 101.

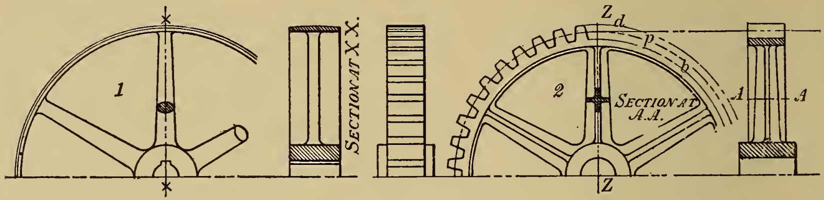


FIG. 102.

The *addendum* line (*d*) and the *root* or *bottom line* (*b*) the same as a dimension line, viz., one long dash and one short dash alternately or a fine continuous *blue* line. The end elevation of the gear-teeth should be made by projecting only the points of the teeth, as shown at No. 2.

CONVENTIONAL METHODS OF SHOWING SCREW-THREADS IN WORKING DRAWINGS.

FIG. 103.—No. 1, shows the convention for a double V thread, U. S. standard; No. 2, a single V thread; No. 3, a single square thread; No. 4, a single left-hand V thread; No. 5, a double right hand square thread; No. 6, any thread of small diameter; No. 7, any thread of very small diameter. The true methods for constructing these threads are explained on pages 99–101, Figs. 137–139.

In No. 6. the short wide line is equal to the diameter of the thread at the bottom. The distance between the longer narrow lines is equal to the pitch, and the inclination is equal to half the pitch.

The short dash lines in No. 7 should be made to correspond to the diameter of the thread at the bottom. After some practice these lines can be drawn accurately enough by the eye.

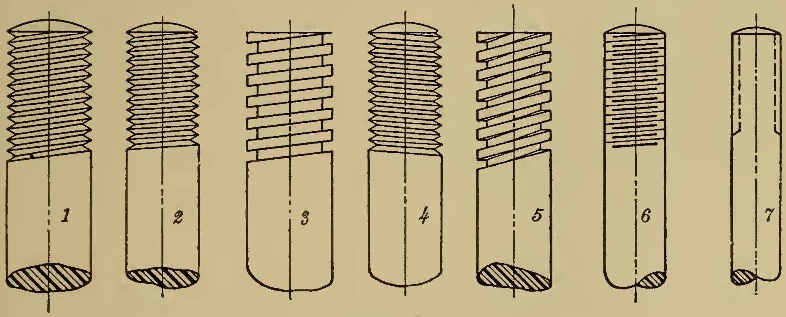


FIG. 103.

CHAPTER IV.

LETTERING AND FIGURING.

THIS subject has not been given the importance it deserves in connection with mechanical drawing. Many otherwise excellent drawings and designs as far as their general appearance is concerned have been spoiled by poor lettering and figuring.

All lettering on mechanical drawings should be plain and legible, but the letters in a title or the figures on a drawing should never be so large as to make them appear more prominent than the drawing itself.

The best form of letter for practical use is that which gives the neatest appearance with a maximum of legibility and requires the least amount of time and labor in its construction.

This would naturally suggest a " free-hand " letter, but before a letter can be constructed " free-hand " with any degree of efficiency, it will be necessary to spend considerable time in acquiring a knowledge of the form and proportions of the particular letter selected.

It is very desirable then that after the student has carefully constructed as many of the following plates of letters and numbers as time will permit and has acquired a sufficient knowledge of the form and proportions of at least the " Roman " and " Gothic " letters; he should then adopt some one style and practice that at every opportunity, until he has attained some proficiency in its free-hand construction.

When practicing the making of letters and numbers free-hand, they should be made quite large at first so as to train the hand.

The " Roman " is the most legible letter and has the best appearance, but is also the most difficult to make well, either free-hand or mechanically. However, the methods given for its mechanical construction, Figs. 104 and 105, will materially modify the objections to its adoption for lettering mechanical drawings.

The " Gothic " letter is a favorite with mechanical draftsmen, because it is plain and neat and comparatively easy to construct. (See Fig. 106.)

Among the type specimens given in the following pages the Bold-face Roman Italic on page 70 is one of the best for a good, plain, clear, free-hand letter, and is often used with good success on working drawings. Gillott's No. 303 steel pen is the best to use when making this letter free-hand.

The "Yonkers" is a style of letter that is sometimes used for mechanical drawings. It is easy to construct with either F. Soennecken's Round Writing-pens, single point, or the Automatic Shading-pen. But it lacks legibility, and is therefore not a universal favorite.

A good style for " Notes " on a drawing is the " Gothic Condensed " shown on page 70.

When making notes on a drawing with this letter, the only guides necessary are two parallel lines, drawn lightly in pencil. The letters should be sketched lightly in pencil first, and then carefully inked, improving spacing and proportions to satisfy the practiced eye.

FIGURING.

Great care should be taken in figuring or dimensioning a mechanical drawing, and especially a working drawing.

To have a drawing accurately, legibly, and neatly figured is considered by practical men to be the most important part of a working drawing.

There should be absolutely no doubt whatever about the character of a number representing a dimension on a drawing.

Many mistakes have been made, incurring loss in time, labor, and money through a wrong reading of a dimension.

Drawings should be so fully dimensioned that there will be no need for the pattern-maker or machinist to measure any part of them. Indeed, means are taken to prevent him from doing so, because of the liability of the workman to make mistakes, so drawings are often made to scales which are difficult to measure with a common rule, such as 2″ and 4″ = 1 ft.

The following books, among the best of their kind, are recommended to all who desire to pursue further the study of "Lettering": *Plain Lettering*, by Prof. Henry S. Jacoby, Cornell University, Ithaca, N. Y.; *Lettering*, by Charles W. Reinhardt, Chief Draftsman, *Engineering News*, New York; *Free-hand Lettering*, by F. T. Daniels, instructor in C. E. in Tufts College.

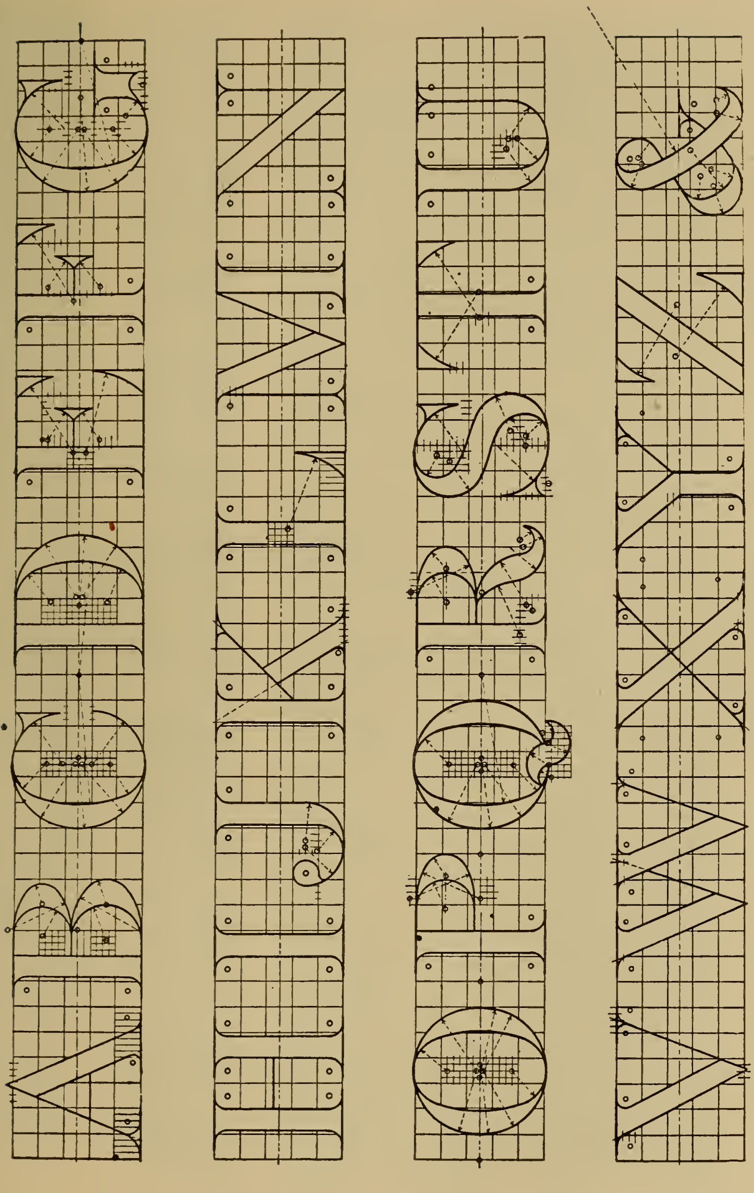


Fig. 104.

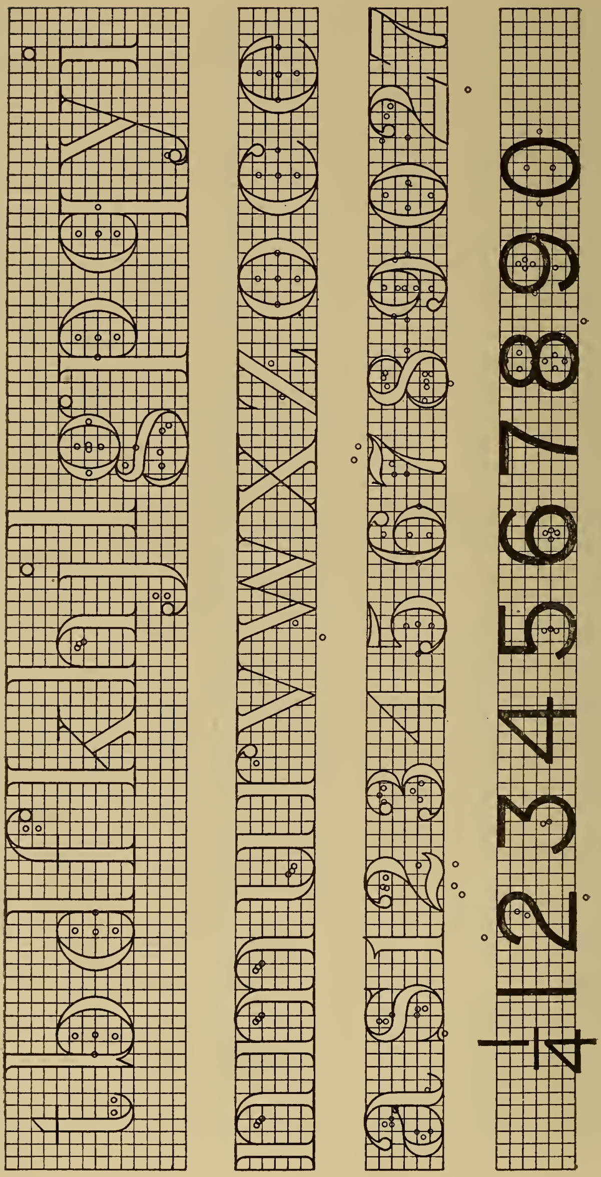


FIG. 105.

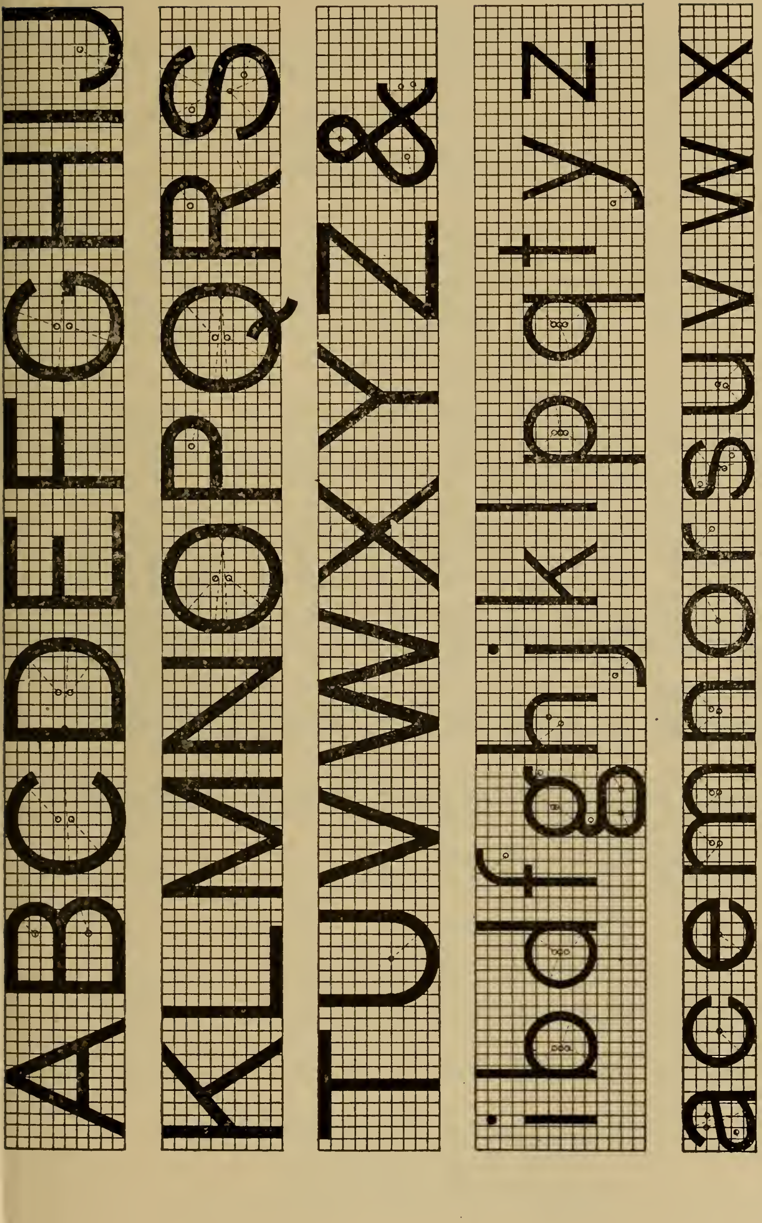

ABCDEFGHIJ
KLMNOPQRS
TUVWXYZ&
ibdfghjklpqtyz
acemnorsuvwx

Fig. 106.

18-Point Roman.

ABCDEFGHIJKLMNOPQRSTUVWX
YZ abcdefghijklmnopqrstuvwxyz
1234567890

18-Point Italic.

ABCDEFGHIJKLMNOPQRSTUV
WXYZ abcdefghijklmnopqrstuvwxyz

12-Point Cushing Italic.

ABCDEFGHIJKLMNOPQRSTUVWXYZ abcdefghijklm
nopqrstuvwxyz 1234567890

28-Point Boldface Italic.

ABCDEFGHIJKLM
NOPQRSTUVWXYZ
abcdefghijklmnopqrstu
vwxyz 1234567890

Two-Line Nonpareil Gothic Condensed.

ABCDEFGHIJKLMNOPQRSTUVWXYZ 1234567890

Three-Line Nonpareil Lightface Celtic.

ABCDEFGHIJKLMNOPQR
STUVWXYZ abcdefghijkl
mnopqrstuvwxyz
1234567890

18-Point Chelsea Circular.

ABCDEFGHIJKLMNOPQRSTUVWX
YZ abcdefghijklmnopqrstuvwxyz
1234567890

18-Point Elandkay.

ABCDEFGHIJKLMNOPQRSTUVWXYZ
1234567890

18-Point Quaint Open.

ABCDEFGHIJKLMNOPQRSTUV
WXYZ 1234567890

28-Point Roman.

ABCDEFGHIJKLM
NOPQRSTUVWXYZ
abcdefghijklmnopqrstu
vwxyz 1234567890

28-Point Old-Style Italic.

ABCDEFGHIJKLMNOP
QRSTUVWXYZ abcdefg
hijklmnopqrstuvwxyz
1234567890

12-Point Victoria Italic.

ABCDEFGHIJKLMNOPQRSTU
VWXYZ 1234567890

18-Point DeVinne Italic.

ABCDEFGHIJKLMNOPQRSTU
VWXYZ abcdefghijklmnopqrst
uvwxyz 1234567890

22-Point Gothic Italic.

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

Double-Pica Program.

ABCDEFGHIJKLMNO
PQRSTUVWXYZ
abcdefghijklmnopqrstuv
wxyz 1234567890

Nonpareil Telescopic Gothic.

ABCDEFGHIJKLMNOPQRSTUVWXYZ 1234567890

24-Point Gallican.

ABCDEFGHIJKL
MNOPQRSTUVW
XYZ 1234567890

Two-Line Virile Open.

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

22-Point Old-Style Roman.

ABCDEFGHIJKLMNOPQRST
UVWXYZ abcdefghijklmnopqrst
uvwxyz 1234567890

36-Point Yonkers.

ABCDEFGHIJKLM
NOPQRSTUVWX
YZ abcdefghijklmnopqr
stuvwxyz 1234567890

CHAPTER V.

ORTHOGRAPHIC PROJECTION.

Orthographic Projection, sometimes called Descriptive Geometry and sometimes simply Projection, is one of the divisions of descriptive geometry; the other divisions are Spherical Projection, Isometric Projection, Shades and Shadows, and Linear Perspective.

In this course we will take up only a sufficient number of the essential principles of Orthographic Projection, Isometric Projection, and Shades and Shade Lines, to enable the student to make a correct mechanical drawing of a machine or other object.

Orthographic Projection is the science and the art of representing objects on different planes at right angles to each other, by projecting lines from the *point of sight* through the principal points of the object perpendicular to the *Planes of Projection*.

There are commonly three planes of projection used, viz., the *H. P.* or *Horizontal Plane*, the *V. P.* or *Vertical Plane*, and the *Pf. P.* or *Profile Plane*.

These planes, as will be seen by Figs. 107 and 109, intersect each other in a line called the *I. L.* or *Intersecting Line*, and form four angles, known as the first, second, third, and fourth *Dihedral Angles.* Figs. 107 and 109 are perspective views of these angles.

An object may be situated in any one of the dihedral angles, and its projections drawn on the corresponding coordinate planes.

Problems in Descriptive Geometry are usually worked out in the first angle, and nearly all English draftsmen project their drawings in that angle, but in the United States the third angle is used almost exclusively. There is good reason for doing so, as will be shown hereafter.

We will consider first a few projection problems in the first angle, after which the third angle will be used throughout.

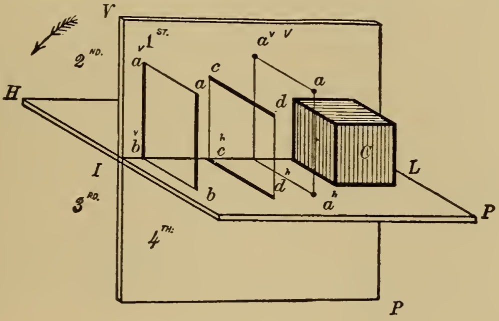


FIG. 107.

H.P., Fig. 107, is the Horizontal Plane, V.P. the Vertical Plane, and I.L. the Intersecting Line.

The Horizontal Projection of a point is where a perpendicular line drawn through the point pierces the H.P.

The Vertical Projection of a point is where a per. line drawn through the point pierces the V.P.

Conceive the point *a*, Fig. 107, to be situated in space 4″ above the H.P. and 3″ in front of the V.P. If a line is passed through the point *a* per. to H.P. and produced until it pierces the H.P. in the point a^h, a^h will be the Hor. Proj. of the point a.

If another line is projected through the point a per. to the V.P. until it pierces the V.P. in the point a^v, a^v is the vertical projection of the point a.

If now the V.P. is revolved upon its axis I.L. in the direction of the arrow until it coincides with the H.P. and let the H.P. be conceived to coincide with the plane of the drawing-paper, the projections of the point a will appear as shown by Fig. 108.

The vertical projection a^v 4″ above the I.L. and the horizontal projection a^h 3″ below the I.L. both in the same straight line.

In mechanical drawing the vertical projection a^v is called the *Elevation* and the horizontal projection a^h the *Plan*.

The projections of a line are found in a similar manner, by first finding the projections of the two ends of the line, and joining them with a straight line.

Let ab be a line in space 3½″ long, parallel to the V.P. and perpendicular to the H.P. One end is resting on the H.P. 2½″ from the V.P.

The points a and b will be vertically projected in the points a^v and b^v. Join a^vb^v. a^vb^v is the vertical projection of the line ab.

When a line is perpendicular to one of the planes of projection, its projection on that plane is a point, and the projection on the other plane is a line equal to the line itself.

ab, Fig. 107, is perpendicular to the H.P., therefore its proj. on the H.P. when viewed in the direction ab will be seen to be a point.

Conceive now the V.P. revolved as before, the V. proj. will be found to be at a^vb^v, Fig. 108, and the H. proj. at the point a^h.

cd, Fig. 107, is a line parallel to the H.P. and perpendicular to the V.P. Its elevation or V. proj. is the point d^v, Fig. 108, and its plan or H. proj. the line c^hd^h perpendicular to the Intersecting Line and equal in size to the line itself.

Planes or Plane Surfaces bounded by lines are projected by the same principles used to project lines and points.

Let aa^vb^vb, Fig. 107, be a plane at right angles to and touching both planes of projection.

The elevation of the front upper corner *a* is projected in the point a^v. The elevation of the front lower corner *b* is projected in the point b^v. Join a^vb^v. a^vb^v is the vertical projection of the front edge *ab* of the plane. The plan of the front upper corner is projected in the point *b* and the point a^v in the the point b^v. A straight line joining bb^v is the plan or horizontal projection of the top edge of the plane.

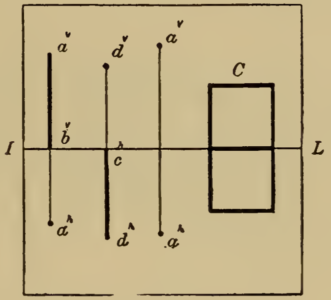


FIG. 108.

On the drawing-paper the plan and elevation of the plane aa^vb *a* would be shown as a continuous straight line a^v to a^h Fig. 108.

Solids bounded by plane surfaces are projected by means of the same principles used to project planes, lines, and points.

C, Fig. 107, is a cube bounded by six equal sides or surfaces. The top and bottom being parallel to the H.P. and the front and back parallel to the V.P., the vert. proj. is a square above I.L. equal in area to any one of the six faces of the cube. The hor. proj. is a similar square below I.L.

These projections are shown at *C*, Fig. 108, as they would appear on the drawing-paper.

The foregoing illustrates a few of the simple principles of projection in relation to points, lines, and solids when placed in the first dihedral angle, and we find that the plan is always *below* and the elevation always *above* the I.L.

Let us now consider the same problems when situated in the *third* angle. The point *a*, Fig. 109, is behind the V.P.

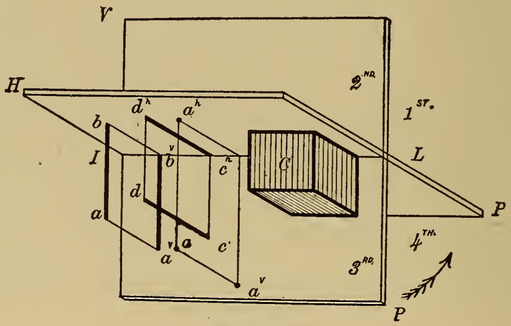


FIG. 109.

and below the H.P. Draw through *a* perpendiculars to the plane of projection. The Hor. proj. is found at a^h and the vert. proj. at a^v.

Conceive again the V.P. to be revolved in the direction of the arrow until it coincides with the H. P. The hor. proj.

will then appear at a^h *above* the I.L. and the vert. proj. at a^v *below* the I.L., Fig. 110. And so with the lines, the planes, and the solids.

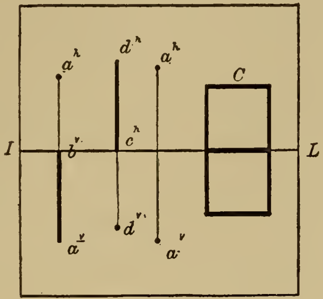


FIG. 110.

In order to still further explain the use of the planes of projection, with regard to objects placed in the third angle, let us suppose a truncated pyramid surrounded by imaginary planes at right angles to each other, as shown by Fig. 111.

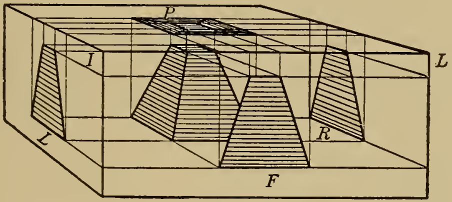


FIG. 111.

With a little attention it will easily be discerned that the pyramid is situated in the third dihedral angle, and that in addition to the V. and H. planes, we have passed two profile planes at right angles to the V. and H. planes, one at the right-hand and one at the left.

When the pyramid is viewed orthographically through each of the surrounding planes, four separate views are had, exactly as shown by the projections on the opposite planes, viz., a Front View, Elevation, or Vert. Proj. at F.; a Right-hand View, Right-end Elevation, or Right-profile Projection at R.; a Left-hand View, Left-end Elevation, or Left-profile Projection at L.; a Top View, Plan or H. Proj. at P.

If we now consider the V.P. and the right and left profile planes to be revolved toward the beholder until they coincide, using the front intersecting lines as axes, the projections of the pyramid will be seen as shown by Fig. 112, which when the imaginary planes and projecting lines have been removed, will be a True Drawing or Orthographic Projection of the truncated pyramid.

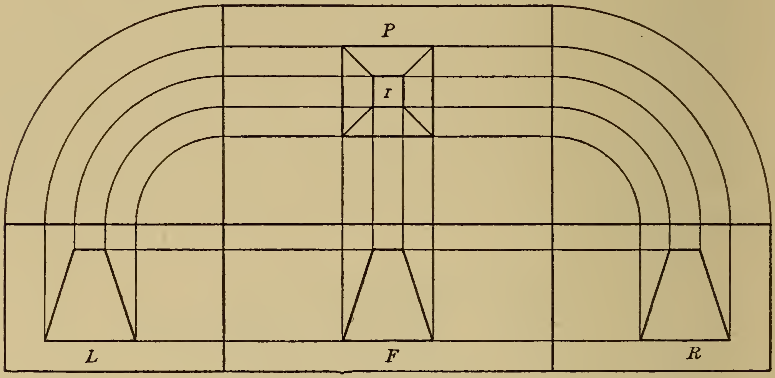


FIG. 112.

NOTATION.

In the drawings illustrating the following problems and their solutions the *given* and *required* lines are shown *wide* and *black*. *Hidden* lines are shown *broken* into short dashes a little narrower than the *visible* lines. *Construction* or *projection* lines are drawn with very narrow *full* or *continuous* black lines.

When convenient very narrow, continuous *blue* lines are sometimes used.

The Horizontal Plane is known as the H.P., the Vertical Plane as V.P. and the Profile Plane as Pf.P.

A point in space is designated by a small letter or figure, its projection by the same letter or figure with small *h* or *v* written above for the horizontal or vertical projection respectively.

In some complicated problems where points are designated by figures their projections are named by the same figures accented.

Drawings should be carefully made to the dimensions given, the scale to be determined by the instructor.

The student should continually endeavor to improve in inking straight lines, curves, and joints.

In solving the following problems the student should have a model of the co-ordinate planes for his own use. This can be made by taking two pieces of stiff cardboard and cutting a slot in the center of one of them large enongh to pass the folded half of the other through it; when unfolding this half a model will be had like that shown by Fig. 107 or 109.

All projections shall now be made from the third, dihedral angle.

PROB. 1.—A point *a* is situated in the third dihedral angle, 1″ below the H.P. and 3″ behind the V.P.

It is required to draw its vertical and horizontal projections.

Draw a straight line $a^h a^v$, Fig. 113, perpendicular to I.L. and measure off the point a^v 1″ below I.L. and the point a^h 3″ above I.L.

a^v is the vertical and a^h the horizontal projection in the same straight line a^va^h.

The student should demonstrate this with his model.

PROB. 2.—Draw two projections of a line 3″ long parallel to both planes, ¾″ below the H.P. and 2″ behind the V.P.

As the line is parallel to both planes, both projections will be parallel to the I.L.

Draw a^vb^v the vert. proj. of the line 3″ long, Fig. 114, parallel to I.L. and ¾″ below it. Draw the hor. proj. 2″ above the I.L. and parallel to it, making it the same length as the vert. proj. by drawing lines perpendicular to I.L. from the points a^v and b^v to a^h and b^h.

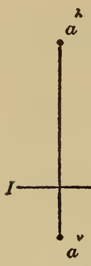


FIG. 113.

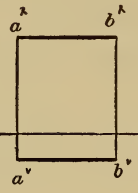


FIG. 114.

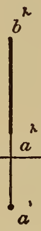


FIG. 115.

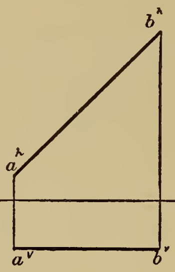


FIG. 116.

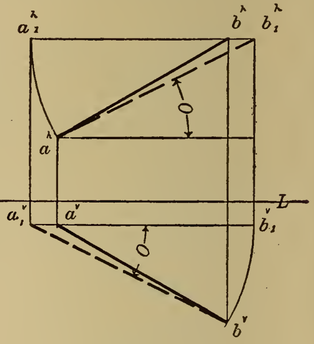


FIG. 117.

PROB. 3.—To draw the hor. and vert. projs. of a straight line 3″ long, per. to the vert. plane, Fig. 115.

As the line is per. to the vert. plane the vert. proj. will be a point below the I.L. and the hor. proj. will be parallel to the horizontal plane and per. to I.L.

PROB. 4.—To draw the plan and elevation of a straight line 6″ long making an angle of 45° with the vert. plane and and par. to the hor. plane, Fig. 116.

The plan or hor. proj. will be above the I.L. and make an angle of 45° with it. The elevation or vert. proj. will be below and par. to I.L.

Draw from the point a^h at any convenient distance from I.L. a straight line a^hb^h 6″ long, making an angle 45° with I.L.

Draw a^vb^v par. to I.L. at a convenient distance below it. The length of the elevation or vert. proj. is determined by dropping perpendiculars from the end of the hor. proj. a^hb^h to the points a^vb^v.

PROB. 5, FIG. 117.—To find the true length of a straight line oblique to both planes of projection and the angle it makes with these planes.

a^vb^v and a^hb^h are the projections of a straight line oblique to V.P. and H.P. Using a^v as a pivot, revolve the line a^vb^v until it becomes parallel to I.L. as shown by $a^vb_1^v$. From the point b_1^v erect a per. Through the point b^h draw a line par. to I.L. cutting the per. in the point b_1^h.

The broken line $a^hb_1^h$ is the true length of the line ab, and the angle o is the true angle which the line makes with V.P.

To find the angle it makes with H.P. :

Using b^h as a pivot, revolve the line b^ha^h until it becomes par. to I.L. as shown by $b^ha_1^h$. From the point a_1^h drop a per. Through the point a^v draw a line par. to I.L. intersecting the per. at the point a_1^vo is the angle which the line ab makes with H.P. and the broken line $a_1^vb^v$ is again its true length.

PROB. 6, FIG. 118.—To project a plane surface of given size, situated in the third angle and par. to the V.P.

Let $abcd$ be the plane surface 3″ long × 2″ wide. If we conceive lines to be projected from the four corners of the plane surface to the V.P. and join them with straight lines we will have its V. projection $a^vb^vc^vd^v$ and shown by Fig. 118. And as the plane surface is par. to the V.P. it must be per to the H.P. since the planes of projection are at right angles to each other. So the plan or H. projection will be a straight line equal in length to one of the sides of the plane surface.

At a convenient distance above I.L. draw a straight line, and from the points a^vb^v project lines at right angles to I.L., cutting the straight line in the points $a^hb.^h$ The line a^hb^h is the hor. proj. of the plane surface *abcd.*

Prob. 7, Fig. 118.—To draw the projections of a plane surface of given dimensions when situated in the third angle perpendicular to the H.P. and making an angle with the V.P.

Let the plane surface be 3″ × 2″ as before and let the angle it makes with V.P. be 60°.

To draw the plan:

At a convenient distance above I.L. and making an angle of 60° with it, draw $a^hb_1^h$, Fig. 118, 2″ long. From b_1^h drop a per. cutting a^vb^v in the point b_1^v and c^vd^v in the point d_1^v, then the rectangle $a^vb_1^vd_1^vc^v$ will be the vert. proj. or elevation of the plane surface *abcd.*

Prob. 8, Fig. 119.—To draw the projections of the same plane surface (1) when parallel to the H.P., (2) when making an angle of 30° with H.P. and per. to V.P., (3) when making an angle of 60° with H.P. and per. to V.P., and (4) when per. to both planes.

Fig. 119 shows the projections; further explanations are unnecessary.

Prob. 9, Figs. 119 and 120.—To draw the projections of the same plane surface when making compound angles with the planes of projection.

Let the plane make an angle of 30° with H.P., as in the second position of Prob. 8, Fig. 119, and in addition to that, revolve it through at angle of 30°. First, draw the plane parallel to H.P., as shown by $a^h c^h b^h d^h$, Fig. 119, the true size of the plane.

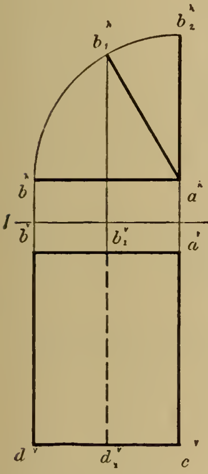

b_1^h
b_2^h
b^h
a^h
I
b^v
b_1^v
a^v
d^v
d_1^v
c^v

FIG. 118.

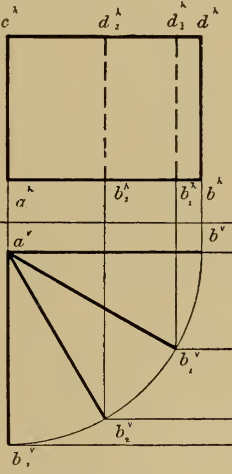

c^h
d_2^h
d_1^h
d^h
a^h
b_2^h
b_1^h
b^h
a^v
b^v
b_1^v
b_2^v
b^v

FIG. 119.

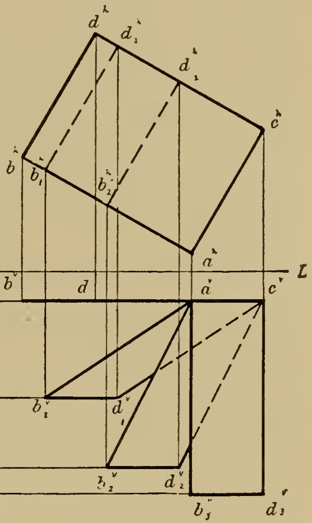

d^h
d_1^h
d_2^h
c^h
b^h
b_1^h
b_2^h
a^h
L
b^v
d^v
a^v
c^v
b_1^v
d_1^v
b_2^v
d_2^v
b_3^v
d_3^v

FIG. 120.

Its elevation will be the straight line $a^v b^v$ parallel to I.L. Next revolve $a^v b^v$, using a^v as a pivot, through an angle of 30°, to the position $a^v b_1^v$, which is its vert. proj. when making an angle of 30° with H.P. Its plan is projected in $a^h b_1^h c^h d_1^h$.

Now as the plane is still to make an angle of 30° with H.P. after it has been revolved through an angle of 30° with relation to the V.P., its hor. proj. will remain unchanged.

With a piece of celluloid or tracing-paper trace the hor. proj. $a^h b_1^h c^h d_1^h$, lettering the points as shown, and revolve the tracing through the angle of 30°, or, which is the same thing, place the tracing so that the line a^hc^h will make an angle of 60° with I.L., and with a sharp conical-pointed pencil transfer the four points to the drawing-paper and join them by straight lines, as shown by Fig. 120.

And as the line a^hc^h retains its position relative to H.P. after the revolution, its elevation will be found at a^vc^v, Fig. 120, in a straight line drawn through a^vb^v, Fig. 119, intersecting perpendiculars from a^hc^h, Fig. 120. And the vert. proj. of the points $b_1^hd_1^h$ will be found at $b_1^vd_1^v$, Fig. 120, in a straight line drawn through b_1^v, Fig. 119, parallel to I.L. and intersecting pers. from $b_1^hd_1^h$, join with straight lines the points $a^vb_1^vc^vd_1^v$.

Draw the projections of the plane when making an angle of 60° with H.P. and revolved through an angle of 30° with relation to V.P.

Draw the projections of the plane when making an angle of 60° with the V.P. and per. to the H.P., Fig. 120.

PROB. 10.—To draw the projections of a plane surface of hexagonal form in the following positions: (1) When one of its diagonals is par. to the V.P. and making an angle of 45° with the H.P. (2) When still making an angle of 45° with the H.P. the same diagonal has been revolved through an angle of 60°.

Draw the hexagon $1^h2^h3^h4^h5^h6^h$, Fig. 121, at any convenient distance above I.L., making the inscribed circle $= 2\frac{1}{2}''$. This will be its hor. proj. and $2^v4^v6^v1^v$ its vert. proj., the diagonal 1^h2^h being par. to both planes of proj. With 1^v as an axis revolve $6^v4^v2^v$ through an angle of 45°. Through the points $2_1^v4_1^v6_1^v$ erect pers. to the points $6_1^h5_1^h4_1^h3_1^h$ and 2_1^h

and join them with straight lines. These are the projs. in the first position. Now trace the hor. proj, 1^h, 2_1^h, etc., on a piece of celluloid or tracing-paper and revolve the tracing until the diagonal $1^h 2_1^h$ makes an angle of 60° with the I.L., Fig. 122. Next draw pers. from the 6 points of the hexagonal plane to intersect hors. from the corresponding points of the elevation in Fig. 121, join the points of intersection with

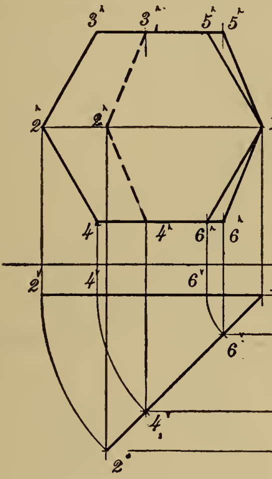


FIG. 121.

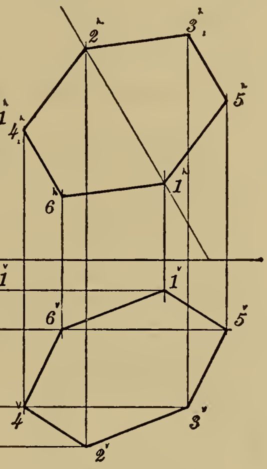


FIG. 122.

straight lines, and so complete the projections of the second position, Fig. 122.

PROB. 11, FIGS. 123 AND 124.—Draw the projs. of a circular plane (1) when its surface is par. to the vert. plane, (2) when it makes an angle of 45° with the V.P., and (3) when still making an angle of 45° with the V.P. it has been revolved through an angle of 60°.

First position: Draw the circular plane 1^v, 2^v, 3^v, 4^v, etc., Fig. 123, below the I.L. with a radius $= 1\frac{1}{2}''$ and divide and figure it as shown.

Since the plane is par. to V.P. its hor. proj. will be a straight line 1^h, 2^h, ... etc.

For the second position revolve the said hor. proj. through the required angle of 45° to the position a^h . . . . $1_1{}^h$, Fig. 123, and through each division in 1^h . . . . a^h draw arcs cutting a^h . . . . 1^h in points $2^h 3^h$ . . . This is the hor. proj. of the plane when making an angle of 45° with the V.P.

The elevation is found by dropping pers. from the points in the hor. proj. a^h . . . $1_1{}^h$ to intersect hor. lines drawn through the correspondingly numbered points in the elevation and through these intersections draw the elevation or vert. proj. of the second position.

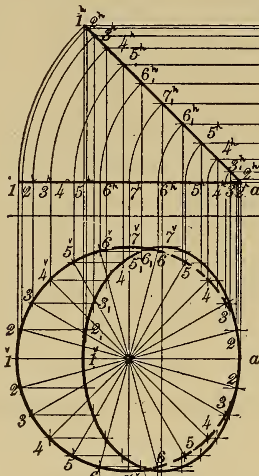


FIG. 123.

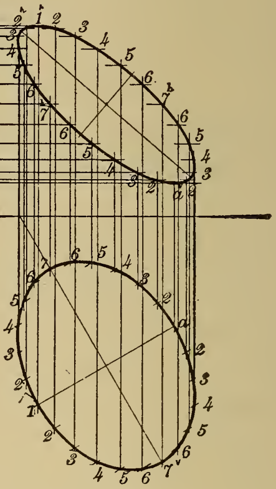


FIG. 124.

For the third position make a tracing of the elevation of the second position, numbering all the points as before, and place the tracing so that the diameter $7^v 7^v$ makes the required angle of 60° with the I.L. and transfer to the drawing-paper.

The result will be the elevation of the third position shown below the I.L., Fig. 124. Its hor. proj. is found by drawing pers. through the points 1, 2, 3, 4 . . . to intersect hors. drawn through the corresponding points in the hor. proj. of the 2d position and through these intersections draw the plan or hor. proj. of the third position, Fig. 124.

PROB. 12, FIG. 125.—Draw the projs. of a regular hexagonal prism, 3″ high and having an inscribed circle of $4\frac{5}{8}''$ diam.: (1) When its axis is par. to the V.P. (2) Draw the true form of a section of the prism when cut by a plane passing through it at an angle of 30° with its base. (3) Draw the projection of a section when cut by a plane passing through *XX*, Fig. 125, per. to both planes of proj.

The drawing of the I.L. may now be omitted.

For the plan of the first part of this prob. draw a circle with a radius = to $2\frac{5}{16}''$, and circumscribe a hexagon about it, as shown by a^h, b^h, b^h, etc., Fig. 125. To project the elevation, draw at a convenient distance from the plan a hor. line par. to a^hd^h, and 3″ below it another line par. to it. From the points $a^hb^hc^hd^h$, drop pers. cutting these par. lines in the points $a^vb^vc^vd^v$, thus completing the elevation of the prism.

Second condition: Draw the edge view or trace of the cutting plane 1′4′, making an angle of 30° with the base of the prism, locating the lower end 4′ one-half inch above the base; parallel to 1′4′, and at a convenient distance from it draw a straight line 1, 4; at a distance of $2\frac{5}{16}''$ on each side of 1, 4 draw lines 3, 2 and 5, 6 parallel to 1, 4, and through the points 1′2′3′4′ let fall pers. cutting these three par. lines in the points 1, 2, 3, 4, 5, 6; join these points by straight lines as shown, and a true drawing of the section of the prism as required will result.

For the third condition of the problem:

Let *XX* be the edge view of the cutting plane and conceive that part of the prism to the right of *XX* to be removed.

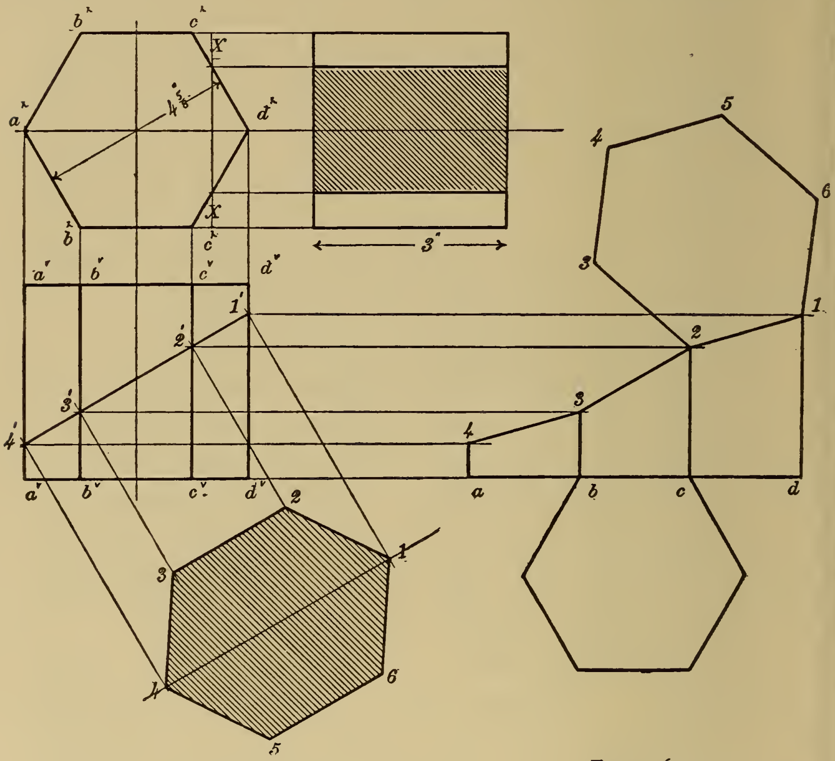

b^h
c^h
X
a^h
d^h
4 5 6
X
b^h
c^h
a^v
b^v
c^v
d^v
1'
2'
3'
4'
a^v
b^v
c^v
d^v
3"
2
3
1
4
6
5
4
5
6
3
1
2
3
4
a
b
c
d

FIG. 125.

FIG. 126.

From the hor. proj. of the prism draw a right-hand elevation or profile proj., and through the points *XX* draw the lines enclosing the section, and hatch-line it as shown.

PROB. 13.—To draw the development of the lower part of the prism in the elevation of the last problem.

To the right of the elevation in Fig. 125, prolong the base line indefinitely and lay off upon it the distances *ab*, *bc*, *cd*, etc., Fig. 126, each equal in length to a side of the hex. At these points erect pers., and through the points $1'2'3'4'$ draw hor. lines intersecting the pers. in 4, 3, 2, 1, etc. At *bc* draw the hex. $a^h b^h b^h, c^h c^h, d^h$ of the last prob. for the base, and at 1, 2 draw the section 1, 2, 3, 4, 5, 6 for the top.

PROB. 14, FIG. 127.—To draw the projs. of a right cylinder 3″ diam. and 3″ long. (1) When its axis is per. to the H.P. (2) Draw the true form of a section of the cylinder, when cut by a plane per. to the V.P. making an angle of 30° with the H.P. (3) Draw a development of the upper part of the cyl.

For the plan of the first condition, describe the circle $1'$, $2'$, etc., with a radius $= 1\frac{1}{2}''$ and from it project the elevation, which will be a square of 3″ sides.

For the second condition: Let 1, 7 be the trace of the cutting plane, making the point 7, $\frac{1}{2}''$ from the top of the cyl. Divide the circle into 12 equal parts and let fall pers. through these divisions to the line of section, cutting it in the points 1, 2, 3, 4, etc. Parallel to the line of section 1, 7 draw $1''7''$ at a convenient distance from it, and through the points 1, 2, 3, 4, etc., draw pers. to 1, 7, intersecting and extending beyond $1''7''$. Lay off on these pers. the distances $6''8'' = 6'8'$, and $5''9'' = 5'9'$, etc., and through the points $2''$, $3''$, $4''$, etc., describe the ellipse.

For the development: In line with the top of the elevation draw the line $g'g''$ equal in length to the circumference of the circle, and divide it into 12 equal parts a', b', etc., a', b'', etc. Through these points drop pers. and through the points

1, 2, 3, etc., draw hors. intersecting the pers. in the points 1, 2, 3, etc., and through these points draw a curve.

Tangent to any point on the straight line draw a 3″ circle for the top of the cyl. and tangent to any suitable point on the curve transfer a tracing of the ellipse.

PROB. 15, FIG. 128.—Draw the projections of a right cone 7″ high, with a base 6″ in diam., pierced by a right cyl. 2″ in diam. and 5″ long their axes intersecting at right angles 3″ above the base of the cone and par. to V.P. Draw first the plan of the cone with a radius = 3″.

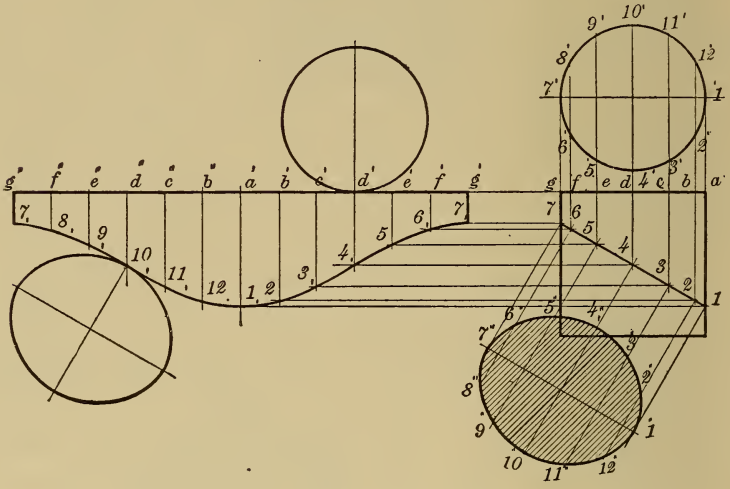


FIG. 127.

At a convenient distance below the plan draw the elevation to the dimensions required.

3″ above the base of the cone draw the center line of the cyl. *CD*, and about it construct the elevation of the cyl., which will appear as a rectangle 2″ wide and 2½″ each side of the axis of the cone. The half only appears in the figure.

To project the curves of intersection between the cyl. and cone in the plan and elevation: Draw to the right of the cyl. on the same center line a semicircle with a radius equal that of the cyl. Divide the semicircle into any number of parts,

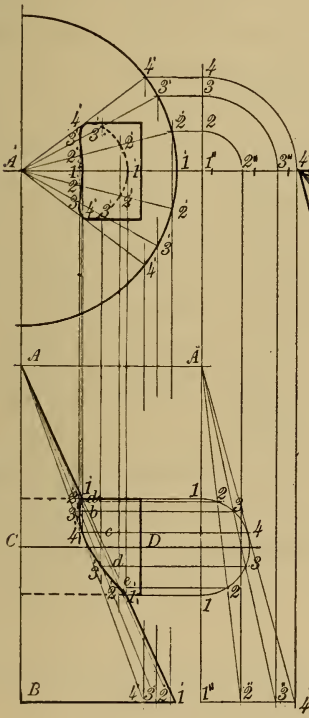


FIG. 128.

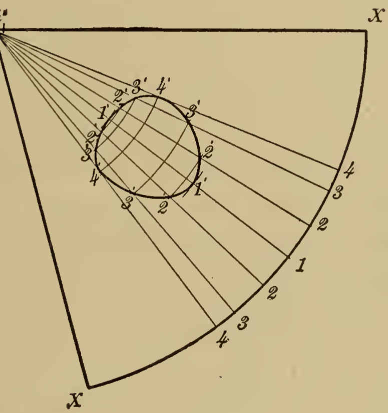


FIG. 129.

as 1, 2, 3, 4, etc. Through 1, 1 draw the per. *A''* 1'' equal in length to the height of the cone, and through *A''* draw the line *A''*4'' tangent to the semicircle at the point 4, and through the other divisions of the semicircle draw lines from *A''* to the line 1''4'', meeting it in the points 3''2''.

From all points on the line 1''4'', viz., 1''2''3''4'', erect pers. to the center line of the plan, cutting it in the points $1_1''2_1''3_1''4_1''$, and with $1_1''$ as the center draw the arcs $2_1''$–2, $3_1''$–3, $4_1''$–4 above the center line of the plan, and through the points 2, 3, 4 draw hors. to intersect the circle of the plan in the points 2′3′4′, and lay off the same distances on the other side of the center line of the plan in same order, viz., 2′3′4′. Through each of these points on the circumference of the circle of the plan draw radii to its center *A*′, and through the same points also in the plan let fall pers. to the base of the elevation of the cone, cutting it in the points 2′3′4′; and from the apex *A* of the elevation of the cone draw lines to the points 2′3′4′ on the base. Hor. lines drawn through the points of division 2, 3, 4 on the semicircle will intersect the elements *A*–2′, *A*–3′, *A*–4′ of the cone in the points 2′3′4′; these will be points in the elevation of the curve of intersection between the cylinder and the cone.

The plan of the curve is found by erecting pers. through the points in the elevation of the curve to intersect the radial lines of the plan in correspondingly figured points, through which trace the curve as shown. Repeat for the other half of the curve.

PROB. 16, FIG. 129.—To draw the development of the half cone, showing the hole penetrated by the cyl.

With center $4_1''$, Fig. 129, and element *A*1′ of the cone, Fig. 128, as radius, describe an arc equal in length to the semicircle of the base of the cone. Bisect it in the line $4_1''1$, and on each side of the point 1 lay off the distances 2, 3, 4, equal to the divisions of the arc in the plan Fig. 128, and from these points draw lines to 4″, the center of the arc. Then with radii *A*–*a*, *b*, *c*, *d*, *e*, respectively, on the elevation Fig. 128, and center $4_1''$ draw arcs intersecting the lines drawn from the arc XX to its center $4_1''$. Through the points of intersection draw the curve as shown by Fig. 129.

PROB. 17, FIG. 130.—To draw the development of the half of a truncated cone, given the plan and elevation of the cone.

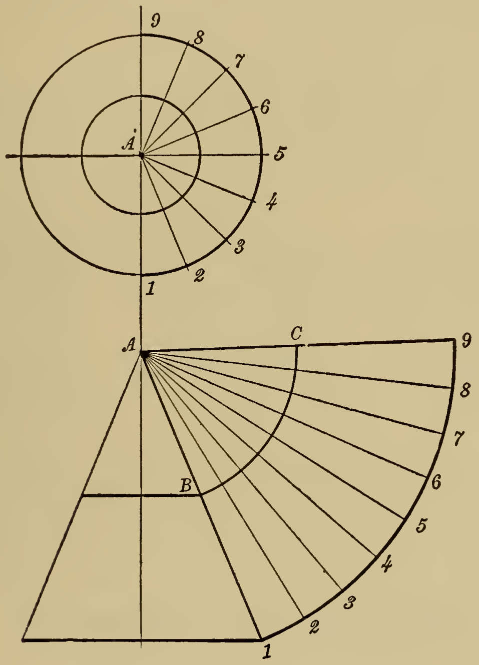


FIG. 130.

Divide the semicircle of the plan into any number of parts, then with A as center and A1 as radius, draw an arc and lay off upon it from the point 1 the divisions of the semicircle from 1 to 9, draw 9A. Then with center A and radius AB draw the arc BC. 1$BC$9 is the development of the half of the cone approximately.

PROB. 18, FIG. 131.—To draw the curve of intersection of a small cyl. with a larger. To the left of the center-line of Fig. 131 is a half cross-section, and to the right a half elevation of the two cyls.

Draw the half plan of the small cyl., which will be a semicircle, and divide it into any convenient number of parts, say 12.

From each of these divisions drop pers.

On the half cross-section these pers. intersect the circumference of the large cyl. in the points 1′, 2′, etc. Through these points draw hors. to intersect in corresponding points the pers. on the half elevation. Through the latter points draw the curve of intersection *C*.

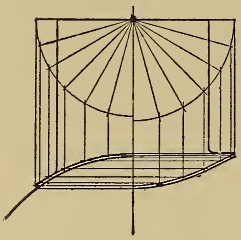


FIG. 134.

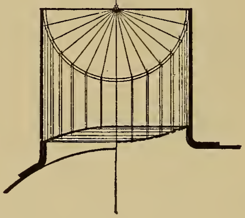


FIG. 133.

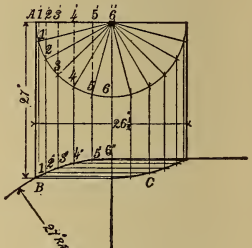


FIG. 131.

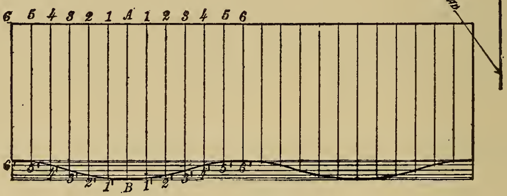

2½" Rad.
6 5 4 3 2 1 A 1 2 3 4 5 6
6′ 5′ 4′ 3′ 2′ 1′ B 1′ 2′ 3′ 4′ 5′ 6′

FIG. 132.

PROB. 19.—To draw the development of the smaller cyl. of the last prob.

Draw a rectangle, Fig. 132, with sides equal to the circumference and length of the cyl. respectively, and divide it into 24 equal parts.

Make AB, 1 1′, 3 3′, etc., Fig. 132, equal to AB, 1′1″, 2′2″, 3′3″, etc., Fig. 131, and draw the developed curve of intersection.

PROB. 20.—To draw the orthographic projections of a cylindrical dome riveted to a cylindrical boiler of given dimensions.

Let the dimensions of the dome and boiler be: dome $26\frac{1}{2}''$ diam. × 27″ high, boiler 54″ diam., plates $\frac{1}{2}''$ thick.

Apply to the solution of this problem the principles explained in Prob. No. 18, Fig. 131.

When your drawings are completed, compare them with Figs. 133 and 134, which are the projections required in the problem.

Letter or number the drawing and be prepared to explain how the different projections were found.

PROB. 21.—To draw the development of the top gusset-sheets of a locomotive wagon-top boiler of given dimensions.

First draw the longitudinal cross-section of the boiler to the dimensions given by Fig. 135, using the scale of 1″ = 1 ft.

Then at any convenient point on your paper draw a straight line, and upon it lay off a distance AB $35\frac{1}{2}''$ long = the straight part of the top of the gusset-sheet G, Fig. 135. With center A and a radius = $27\frac{7}{8}''$ (the largest radius of the gusset) + 6″ (the distance from the center of the boiler to the center of the gusset C, Fig. 135) = $33\frac{7}{8}''$, draw arc 1.

With center B and a radius = $26\frac{7}{8}''$ (the smallest radius of the gusset) draw arc 2. Tangent to these arcs draw the straight line 1, 2 extended, and through the points *A* and draw lines 1, *A* and 2, *B* per. to 1, 2.

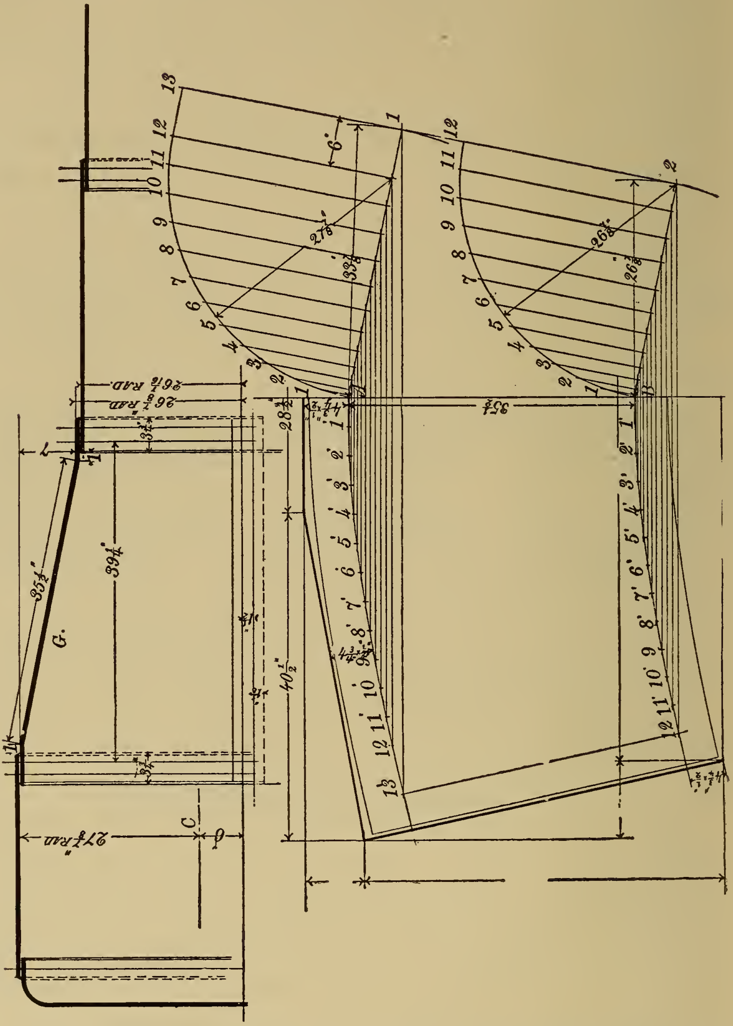

13
12
11
10
9
8
7
6
5
4
3
2
1
6"
27⅞"
33⅞
26⅝"
26⅝
35¼
26⅝ RAD.
26⅞ RAD.
3¼"
39¼"
35¼"
G.
1"
3¼"
28½
40½"
27¼ RAD.
C
D
A
B

Fig. 135.

Fig. 136.

Take a point on the per. 1, 2, 6″ from the point 1 as a center and through the point *A* draw an arc with a radius = 27⅞″.

With point 2 as a center and $2B$ as a radius ($26\frac{7}{8}''$) draw an arc through B to meet the line 1, 2.

Divide both arcs into any number of parts, say 12, and through these divisions draw lines per. to and intersecting $1A$ and $2B$ respectively. Through these intersections draw indefinite hors. and on these hors. step off the length of the arcs, with a distance = one of the 12 divisions as follows:

On the first hors. lay off the length of the arc $A1'$ and $B1'$ $= A1$ and $B1$ respectively. Then from $1'$ lay off the same distance to $2'$ on the second hors. etc. Through these points draw curves $A13'$ and $B12'$. Join points $12'$ and $13'$ with a straight line. Then $AB12$, 13 will be the developed half of the straight part of the gusset.

On the two ends or front and back of the gusset we have now to add $1''$ for clearance $+ 3\frac{3}{4}''$ for lap $+ \frac{1}{2}''$ allowance for truing up the plates, total $= 5\frac{1}{4}''$. And to the sides $2\frac{5}{8}''$ for lap $+ \frac{1}{2}''$ allowance for truing up, total $= 3\frac{1}{8}''$.

The outline of the developed sheet may now be drawn to include these dimensions with as little waste as possible, as shown by Fig. 136. Extreme accuracy is necessary in making this drawing, as the final dimensions must be found by measurement.

PROB. 22.—To draw the projections of a V-threaded screw and its nut of $3''$ diam. and $\frac{3}{4}''$ pitch.

Begin by drawing the center line C, Fig. 137, and lay off on each side of it the radius of the screw $1\frac{1}{2}''$. Draw AB and $6D$. Draw $A6$ the bottom of the screw, and on AB step off the pitch $= \frac{3}{4}''$, beginning at the point A.

On line $6D$ from the point 6 lay off a distance = half the pitch $= \frac{3}{8}''$, because when the point of the thread has completed half a revolution it will have risen perpendicularly a distance = half the pitch, viz., $\frac{3}{8}''$.

Then from the point 6″ on 6*D* step off as many pitches as may be desired. From the points of the threads just found, draw with the 30° triangle and T-square the V of the threads intersecting at the points *b* . . *b* . . the bottom of the threads.

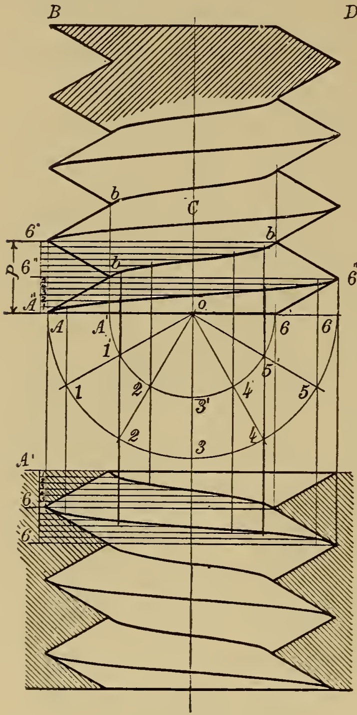


FIG. 137.

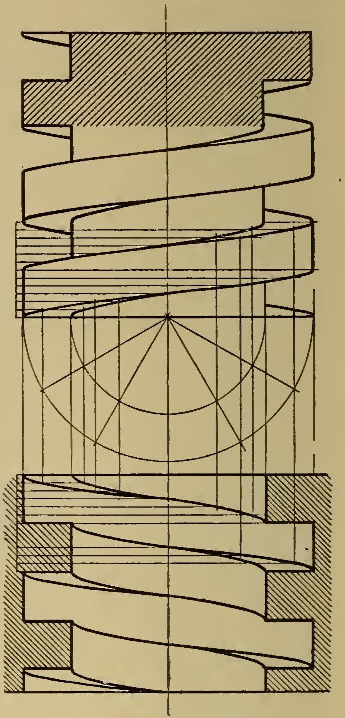


FIG. 138.

At the point *O* on line *A*6 draw two semicircles with radii || the top and bottom of the thread respectively. Divide these into any number of equal parts and also the pitch *P* into the same number of equal parts. Through these divisions draw hors. and pers. intersecting each other in the points as shown by Fig. 137, which shows an elevation partly in section and a section of a nut to fit the screw. Through the points of intersection draw the curves of the helices shown, using No. 3 of the "Sibley College Set" of Irregular Curves.

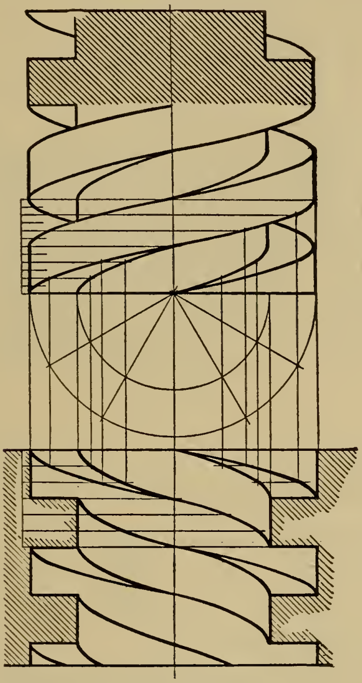


Fig. 139.

Prob. 22.—To draw the proj. of a square-threaded screw 3″ diam. and 1″ pitch and also a section of its nut.

The method of construction is the same as for the last problem, and is illustrated by Fig. 138.

Prob. 22.—To draw the projections of a square double threaded screw of 3″ diam. and 2″ pitch, and also a section of its nut.

The solution of this problem is shown by Fig. 139, and further explanation should be unnecessary.

PROB. 23.—To draw the curve of intersection that is formed by a plane cutting an irregular surface of revolution.

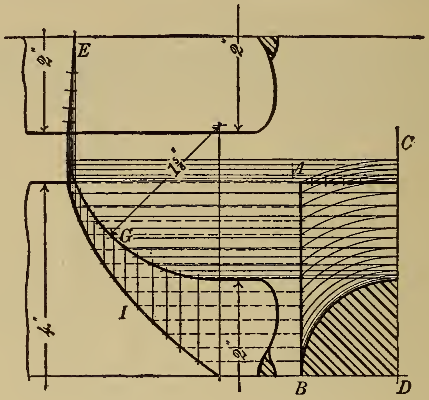


FIG. 140.

Figs. 140, 141, and 142 show examples of engine connecting rod ends where the curve *I* is formed by the inter-section of the flat stub end with the surface of revolution of the turned part of the rod.

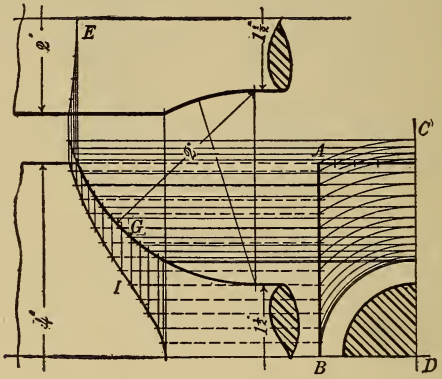


FIG. 141.

The method of finding the curves of intersection are so plainly shown by the figures that a detailed explanation is deemed unnecessary.

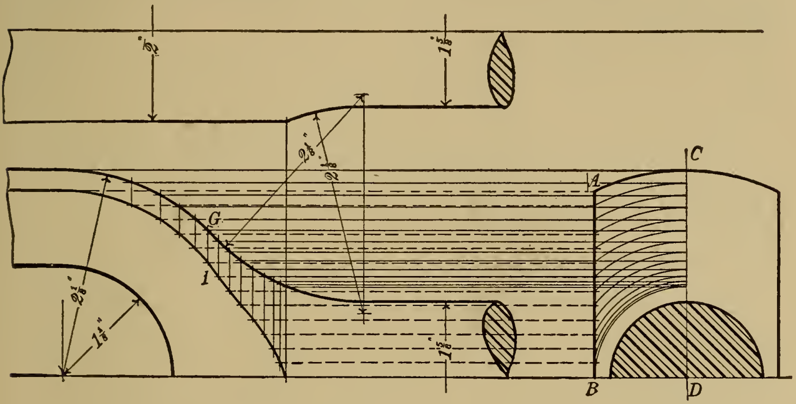


FIG. 142.

SHADE LINES, SHADES AND SHADOWS.

Shade Lines are quite generally used on engineering working drawings; they give a relieving appearance to the projecting parts, improve the looks of the drawing and make it easier to read, and are quickly and easily applied.

The *Shading* of the curved surfaces of machine parts is sometimes practiced on specially finished drawings, but on working drawings most employers will not allow shading because it takes too much time, and is not essential to a quick and correct reading of a drawing, especially if a system of shade lines is used.

Some of the principles of shade lines and shading are given below, with a few problems illustrating their commonest applications.

The *shadows* which opaque objects cast on the planes of projection or on other objects are seldom or never shown on a working drawing, and as the students in Sibley College are taught this subject in a course on Descriptive Geometry, it is omitted here.

CONVENTIONS.

The Source of Light is considered to be at an infinite distance from the object, therefore the Rays of Light will be represented by parallel lines.

The Source of Light is considered to be fixed, and the Point of Sight situated in front of the object and at an infinite distance from it, so that the *Visual Rays* are parallel to one another and per. to the plane of projection.

Shade Lines divide illuminated surfaces from dark surfaces.

Dark surfaces are not necessarily to be defined by those surfaces which are darkened by the shadow cast by another part of the object, but by reason of their location in relation to the rays of light.

It is the general practice to shade-line the different projections of an object as if each projection was in the same plane, e.g., suppose a cube, Fig. 143, situated in space in the third angle, the point of sight in front of it, and the direction of the rays of light coinciding with the diagonal of the cube, as shown by Fig. 144. Then the edges $a^v b^v$, $b^v c^v$ will be shade lines, because they are the edges which separate the illuminated faces (the faces upon which fall the rays of light) from the shaded faces, as shown by Fig. 144.

Now the source of light being fixed, let the point of sight remain in the same position, and conceive the object to be revolved through the angle of 90° about a hor. axis so that a plan at the top of the object is shown above the elevation, and as the projected rays of light falling in the direction of the diagonal of a cube make angles of 45° with the hor., then with the use of the 45° triangle we can easily determine that the lower and right-hand edges of the plan as well as of the elevation should be shade lines.

This practice then will be followed in this work, viz.:

Shade lines shall be applied to all *projections* of an object, considering the rays of light to fall upon each of them, from the same direction.

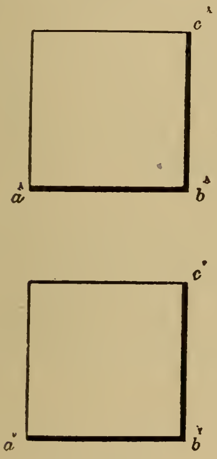


FIG. 143.

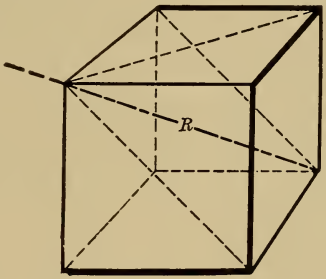


FIG. 144.

Shade lines should have a *width* equal to 3 times that of the other outlines. *Broken lines* should never be shade lines.

The outlines of *surfaces of revolution* should not be shade lines. The shade-lined figures which follow will assist in illustrating the above principles; they should be studied until understood.

SHADES.

The *shade* of an object is that part of the surface from which light is excluded by the object.

The *line of shade* is the line separating the shaded from the illuminated part of an object, and is found where the rays of light are tangent to the object.

Brilliant Points.—"When a ray of light falls upon a surface which turns it from its course and gives it another direction, the ray is said to be reflected. The ray as it falls upon the surface is called the incident ray, and after it leaves the surface the reflected ray. The point at which the reflection takes places is called the *point of incidence.*

"It is ascertained by experiment—

"(*a*) That the plane of the incident and reflected rays is always normal to the surface at the point of incidence;

"(*b*) That at the point of incidence the incident and reflected rays make equal angles with the tangent plane or normal line to the surface.

"If therefore we suppose a single luminous point and the light emanating from it to fall upon any surface and to be reflected to the eye, the point at which the reflection takes place is called the brilliant point. The brilliant point of a surface is, then, the point at which a ray of light and a line drawn to the eye make equal angles with the tangent plane or normal line—the plane of the two lines being normal to the surface." —Davies: *Shades and Shadows.*

Considering the rays of light to be parallel and the point of sight at an infinite distance, the brilliant point on the surface of a *sphere* is found as follows: Let A^vC^v and A^hC^h, Fig.

145, be a ray of light and A^vA^h a visual ray. Bisect the angles contained between the ray of light and the visual ray as follows: Revolve A^vC^v about the axis A^v until it becomes parallel to the hor. plane at $A^vC_1^v$. At C_1^v erect a per. to intersect a hor. through C^h at C_1^h join $C_1^hL^h$ (L may be any convenient

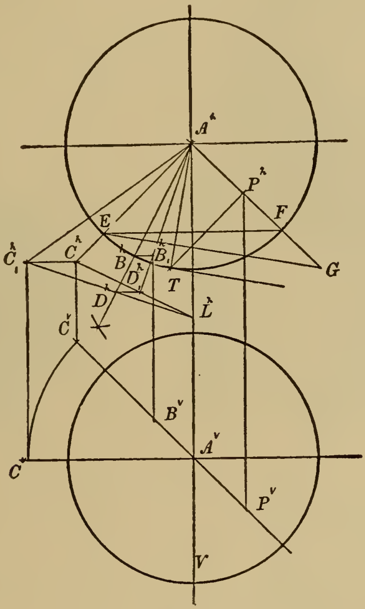


FIG. 145.

point on the line of vision), bisect the angle $L^hA^hC_1^h$ with the line A^hD^h. Join C^hL^h and through the point D^h, draw a hor. cutting C^hL^h at D_1^h, then $A^hD_1^h$ is the hor. projection of the bisecting line. A plane drawn per. to this bisecting line and tangent to 'the sphere touches the surface at the points $B^vB_1^h$ where the bisecting lines pierce it. Therefore B^vB^h are the two projections of the brilliant point.

The point of shade can be found as follows:

Draw A^hG, Fig. 145, making an angle of 45° with a hor. Join the points E and F with a straight line EF. Lay off on A^hG a distance equal to EF, and join EG. Parallel to EG draw a tangent to the sphere at the point T. Through T draw TP^h per. to A^hG. From the point P^h drop a per. to P^v. P^v is the point of shade.

FIG. 146.

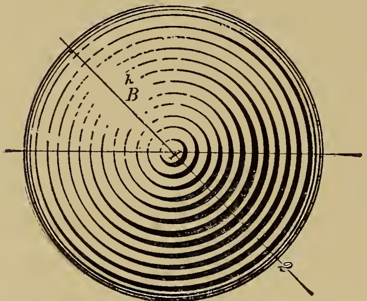
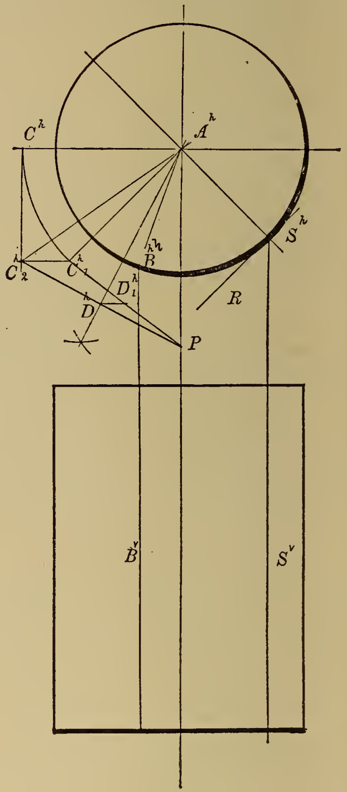
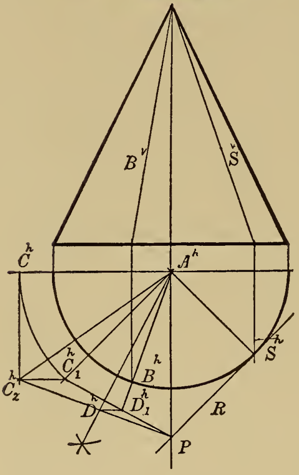


FIG. 147.



C^h
A^h
C_2^h
C_1^h
B^h
D_1^h
D^h
S^h
R
P
B^v
S^v



B^v
S^v
C^h
A^h
C_1^h
C_2^h
B^h
S^h
D^h
D_1^h
R
P

FIG. 148.

PROB. 24.—To shade the elevation of a sphere with graded arcs of circles.

First find the brilliant point and the point of shade, and divide the radius 1, 2 into a suitable number of equal parts, and draw arcs of circles as shown by Fig. 146, grading them by moving the center a short distance on each side of the center of the sphere on the line B^h2 and varying the length of the radii to obtain a grade of line that will give a proper shade to the sphere. It is desirable to use a horn center to protect the center of the figure.

Fig. 149 shows the stippling method of shading the sphere.

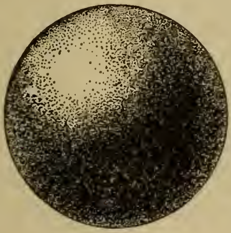


FIG. 149.

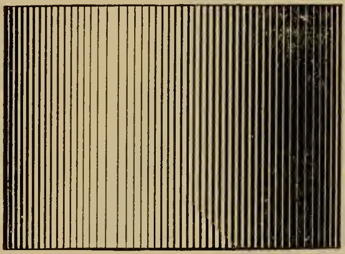


FIG. 150.

PROB. 25.—To shade a right cylinder with graded right lines.

Find the line of light B^v by the same method used to find the brilliant point on the sphere, except that the line of light is projected from the point B^h where the bisection line A^hD cuts the circle of the cylinder.

The line of shade is found where a plane of rays is tangent to the cyl. at S^v and S^h.

Fig. 150 shows how the shading lines are graded from the line of shade to the line of light.

It will be noticed that the lines grow a little narrower to the right of the line of shade on Fig. 150; this shows where the reflection of the rays of light partly illumine the outline of the cylinder.

PROB. 26, FIG. 148.—To shade a right cone with graded right lines tapering toward the apex of the cone.

Find the elements of light and shade as shown by Fig. 148, and draw the shading-lines as shown by Fig. 151, grading their width toward the light and tapering them toward the apex of the cone.

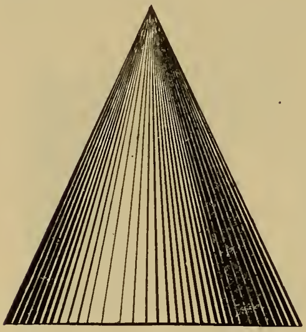


FIG. 151.

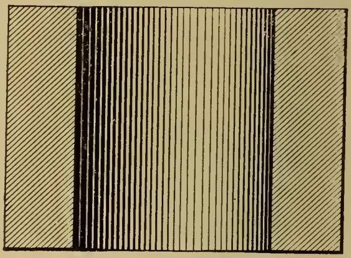


FIG. 152.

The mixed appearance of the lines near the apex of the cone on Fig. 151 can usually be avoided by letting each line dry before drawing another through it, or as some draftsmen do, stop the lines just before they touch.

PROB. 27.—To shade the concave surface of a section of a hollow cylinder.

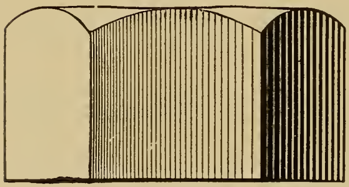


FIG. 153.

Find the element of light and grade the shading lines from it to both edges as shown by Fig. 152.

Fig. 153 shows a conventional method of shading a hexagonal nut.

SHADOWS.

Let *R*, Fig. 154, be the direction of the rays of light and *C* an opaque body between the source of light and a surface *S*. The body *C* will prevent the rays from passing in that direction, and its outline will be projected at *D* on the surface *S*. *D* is the *shadow* of *C*.

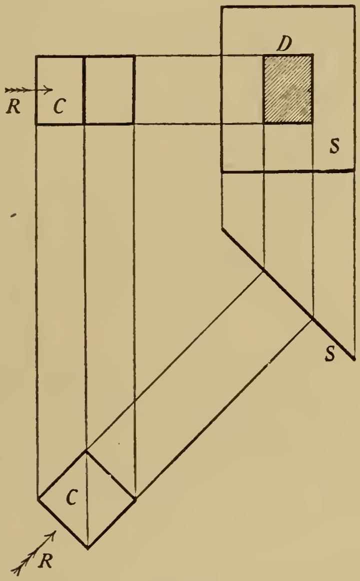


FIG. 154.

The line which divides the illuminated portion of the surface *S* from the shadow *D* is called the *line of shadow*.

Shadow of a Point.—If a line is drawn through a point in space in a direction opposite to the source of light, the point in which this line pierces the plane of projection is the shadow of the point on that plane.

To find the shadow on the H.P. of a point in space in the first dihedral angle:

Let A, Fig. 155, be the point in space, and R the direction of the ray of light; then A_1^H is the shadow of the point A on H.P., and $A^HA_1^H$ is the hor. proj. and $A^VA_1^V$ the vert. proj. of R. B^V is the point where R pierces V when prolonged below H.P., and B^H is its hor. proj. in the G.L. The projections of R would then be A^VB^V and A^HB^H.

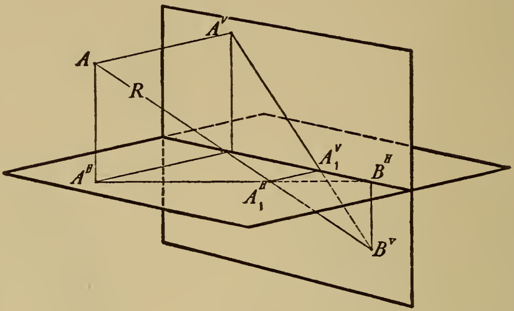


FIG. 155.

The shadow of a point in V may be found in a similar manner,

Shadows of Right Lines.—The shadow of a right line on a plane may be determined by finding the shadows of two of its points and joining these by a right line; e.g., the shadow of the line AB, Fig. 156, on H.P. is found as follows:

Through the points A^VB^V draw the rays $A^VA_1^V$ and $B^VB_1^V$ to intersect the plane of projection in G.L. in the points A_1^V and B_1^V; from these points drop perpendiculars to meet rays drawn through A^H and B^H in the points A_1^H and B_1^H. A line drawn from A_1^H to B_1^H is the shadow of AB on H.P.

If a right line is parallel to the plane of projection its shadow will be parallel to the line itself.

If a line coincides with a ray of light, its shadow on any surface will be a point.

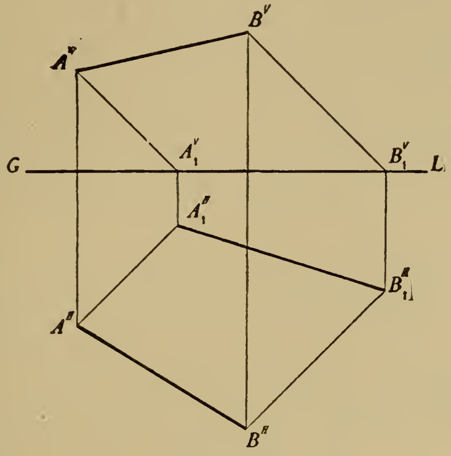

B^V
A^V
G
A_1^V
B_1^V
L
A_1^H
B_1^H
A^H
B^H

FIG. 156.

PROB. 28.—*To find the shadow of a right line on V.P. and H.P.:*

Let *AB*, Fig. 157, be the given line. Find the shadows

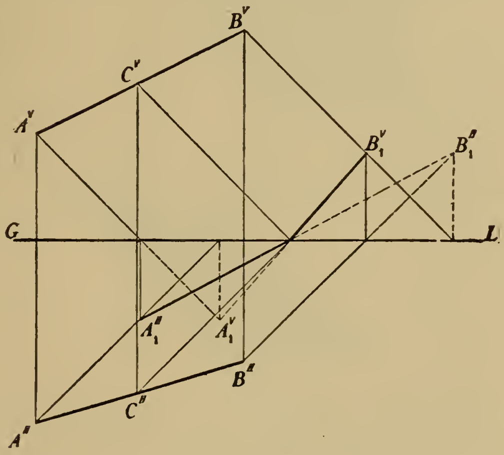

B^V
C^V
A^V
B_1^V
B_1^H
G
L
A_1^H
A_1^V
B^H
C^H
A^H

FIG. 157.

of the points A and B by passing rays through each of their projections to make angles of 45° with G.L. The shadow of A^H on H.P. is found at A_1^H, and that of B^H at B_1^H, where the rays through these points intersect the H.P. The shadow of A^V on V.P. is found at A_1^V and that of B^V at B_1^V, where the rays through these points intersect V.P. Join A_1^H and B_1^H with a straight line and we have the shadow of AB on H.P., and the shadow on V.P. is found in the same way by joining with a straight line the points A_1^V and B_1^V.

That part of the shadow which falls on V.P. below G.L., and on H.P. above G.L., is called the *secondary* shadow, because it makes a second intersection, i.e., it is conceived to have passed through V.P. and made an intersection with H.P. behind V.P. With the use of the secondary shadow problems like this are easier of solution.

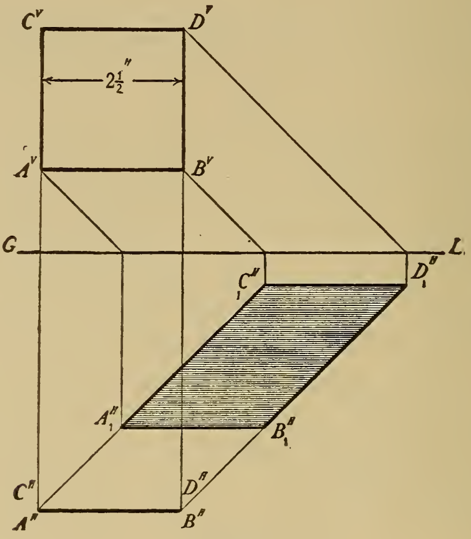


FIG. 158.

PROB. 29.—*ABCD, Fig. 158, is a square plate parallel to V.P.; find its shadow on H.P.*

Through the points A^V, B^V, D^V, and A^HC^H, B^HD^H, draw rays making the angle of 45° (or any other angle which may be adopted) with G.L., and determine the shadows of these points as explained in Fig. 155. They will be found in the points $A_1^HB_1^H$, C_1^H, D_1^H. Join these points with right lines and they will form the line of shadow of the square plate on H.P.

PROB. 30.—*To find the shadow of a cube on V.P. with one face in V.P. and the other faces parallel or perpendicular to H.P.*

Fig. 159 shows the cube in the given position. The line of shade is composed of edges *EF*, *FG*, *GD*, *DB*, and the edges *AE* and *AB* in V.P. which coincide with their shadows.

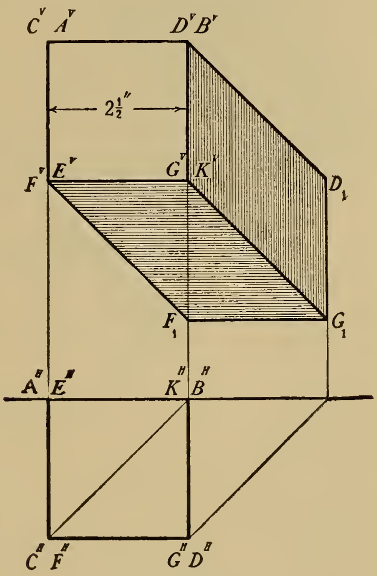


FIG. 159.

The shadow of EF is E^VF_1, of FG is F_1G_1, of GD is G_1D_1, of DB is D_1B^V. The shadows of the edges AE and AB coincide with the lines. These shadows are found by the same rules used for finding the shadows of a line in Prob. 28. The line of shadow is $B^VD_1G_1F_1F^VE^VA^VD^V$. The visible line of shadow is $B^VD_1G_1F_1E^VC^VD^V$.

PROB. 31.—*To find the shadow of a rectangular abacus on the face of a rectangular pillar.*

Assume the hor. and vert. projs. of the abacus and pillar to be as shown in Fig. 160.

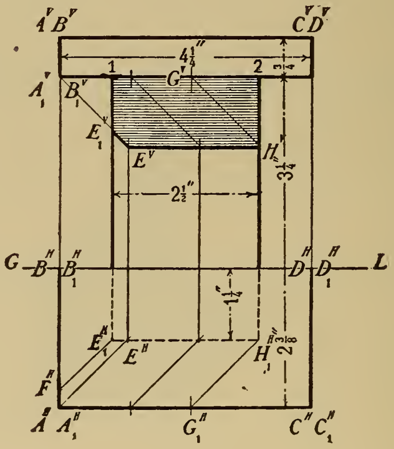

A^V B^V
C^V D^V
$4\frac{1}{4}''$
1
2
$\frac{3}{4}$
G^V
A_1^V
B_1^V
E_1^V
E^V
H^V
$3\frac{1}{4}''$
$2\frac{1}{2}''$
G
B^H
B_1^H
D^H
D_1^H
L
$1\frac{1}{4}''$
E_1^H
E^H
H_1^H
$2\frac{3}{8}''$
F^H
A^H
A_1^H
G_1^H
C^H
C_1^H

FIG. 160.

The line of shade of the abacus is seen to be the edges $A_1^HB_1^H$ and $A_1^HC_1^H$. The plane of rays through edge $A_1^HB_1^H$ is per. to V.P., and the line $A_1^VE^V$ is its vert. proj. or trace; its hor. trace is $A_1^HE^H$. The shadow on the left side face, is vertically projected in the point E_1^V where the plane of rays intersects that face. The ray through the point A_1^H pierces the front face in the point E^H, which is the shadow of A_1^H, and $E_1^HE^H$, $E_1^Ve^V$ is the shadow of the part $F^HA_1^H$ on this face.

The line $A_1^HC_1^H$ is parallel to the front face, therefore its shadow on it will be parallel to itself and pass through E.

The visible line of shadow is now found to be 1 $E_1^VE^VH^V$ 2 1.

PROB. 32.—*Construct the shade of an upright hex. prism and its shadow on both planes.*

Fig. 161 shows the given prism with its line of shade

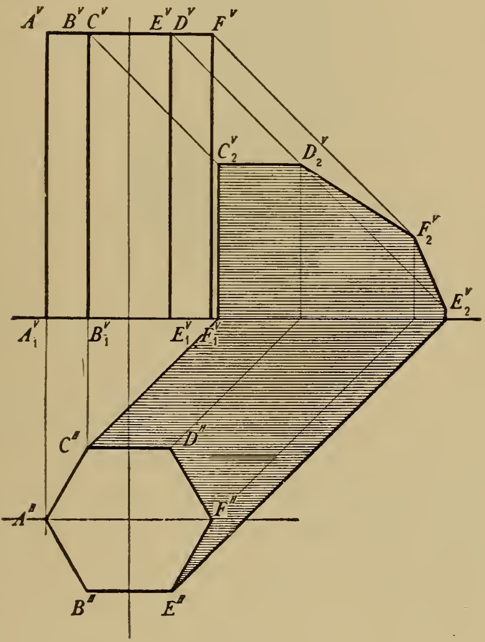


FIG 161.

$A_1^VB_1^VE_1^VD^VF^V$ on the vert. proj., $C^HD^HF^HE^H$ on the hor. proj., and its shadow on both planes.

PROB. 33.—*Given a circular plate parallel to one coordinate plane; construct its shadow on the other plane.*

Let $A^VB^VC^VD^V$ and A^HC^H, Fig. 162, be the projections of the circular plate.

Circumscribe a square E^VG^V about the circle; its shadow on H.P. will be the parallelogram A^HG^H, and the shadows of the points $A^VB^VC^VD^V$ are projected in the points $A_1^HB_1^HC_1^HD_1^H$. The shadow of the inscribed circle is an ellipse tangent to the parallelogram at the points $A_1^HB_1^HC_1^HD_1^H$, with $B_1^HD_1^H$ and $A_1^HC_1^H$ as conjugate diameters.

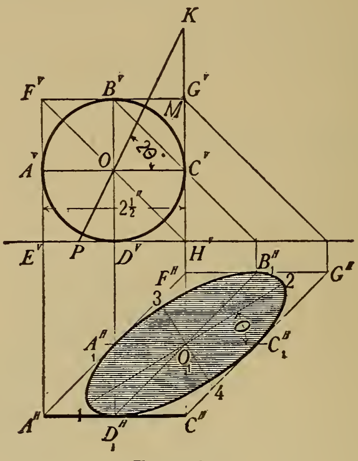


Fig. 162.

The position and length of the axes of the ellipse of shadow may be found as follows:

Erect a perpendicular at the point C^V making G^VK^V equal to radius of the circle· draw KOP; then KP is equal to the major and MK to the minor axis, and angle θ is twice the angle of the transverse axis with the horizontal conjugate diam.; i.e., KP is equal to 1, 2, MK to 3, 4, and 2, $O_1C_1^H$, or angle θ, is equal to half KOC^V, PROB. 34.—*Find the shade of a cylindrical column and abacus, and the shadow of the abacus on the column.*

Let $A^VB^VC^V$ and $A^HB^HC^H$, Fig. 163, be the projections of the abacus, $D^HE^HF^H$ and $D^HD^VG^VF^H$ the projections of the column.

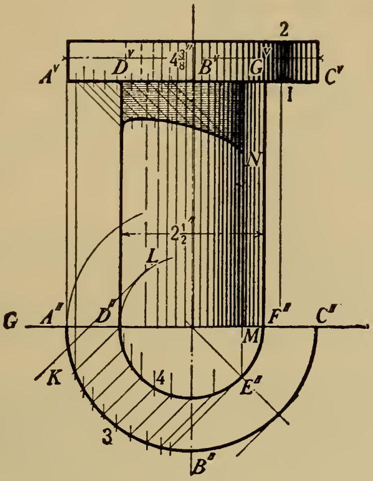


FIG. 163.

The line of shade on the column is found by passing two planes of rays tangent to the column perpendicular to H.P. and parallel to the hor. proj. of the ray of light. KL and E^H are the traces of these planes tangent to the column at the points L, and E^H and MN the visible line of deepest shade on the cylindrical column.

The deepest line of shade 1, 2 on the abacus is found in the same way.

The line of shadow on the column of that portion of the lower circumference of the abacus which is toward the source of light is found by passing vertical planes of rays, as 3, 4, to determine any number of points in the line, and joining these points by a line as shown in Fig. 163.

PROB. 35.—*Find the shade of an oblique cone and its shadow on H.P.*

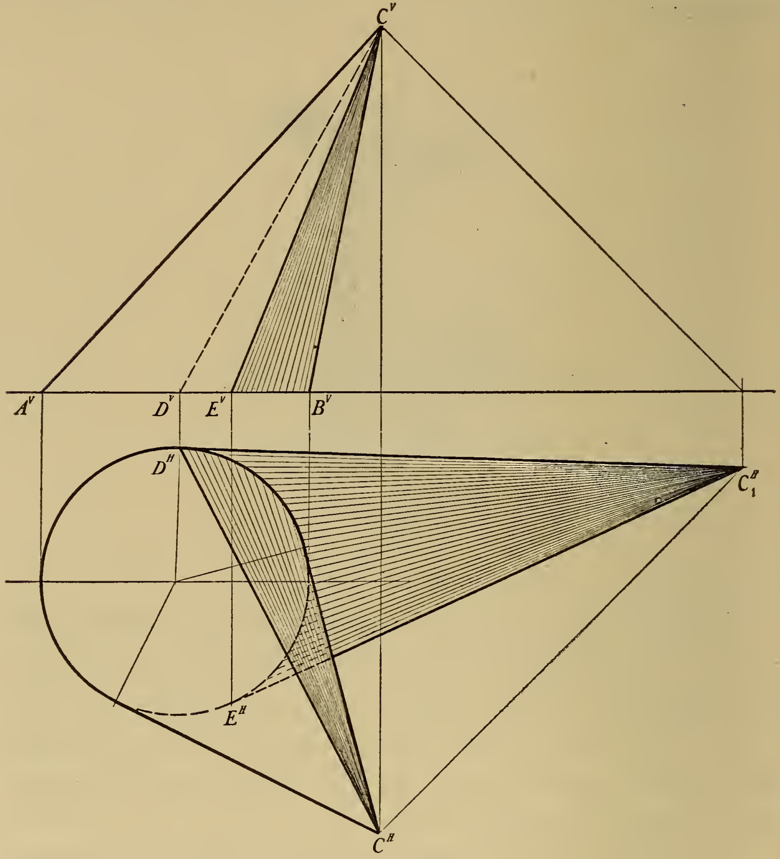


FIG. 164.

Take the cone as given in Fig. 164. Pass two planes of rays tangent to the cone; their elements of contact will be the deepest lines of shade. To determine the elements of contact draw a ray through C^V; $C_1{}^H$ is its hor. trace. From

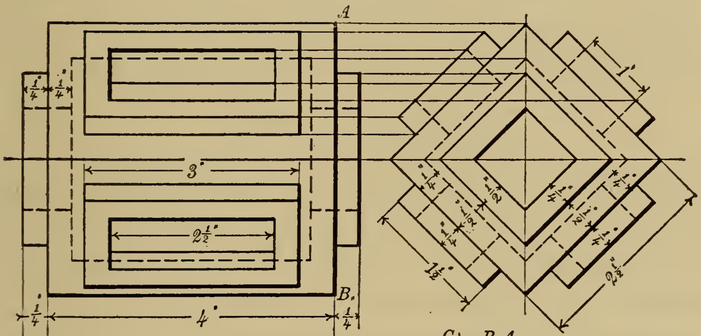
C_1^H draw lines tangent to the base at D and E; the lines of contact are CE and CD, and ECD is the line of shade.

The visible line of shade on H.P. is $E^H D^H$, and on V.P. it is $C^V E^V$. The shadow on H.P. is $E^H C_1^H D^H$.

PROB. 36.—To draw a front and end elevation of a rectangular hollow box with a rectangular block on each face, each block to have a rectangular opening, and all to be properly shade-lined and drawn to the dimensions given on Fig. 165.

Draw the hor. center line first, and then the vertical center line of the end view. About these center lines on the end el-

FIG. 165.



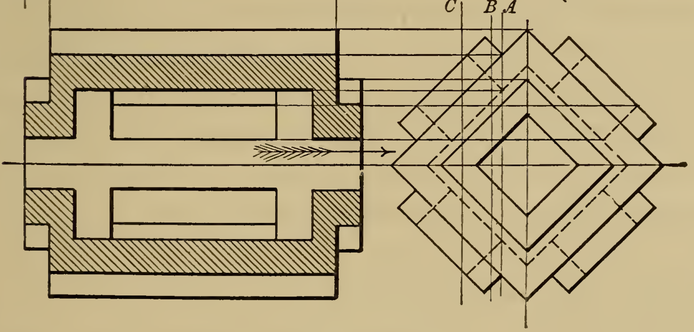


FIG. 166.

evation construct the squares shown and erect the edges of the blocks. Next draw the hidden lines indicating the thickness of the walls of the box and the openings through the blocks, measuring the sizes carefully to the given dimensions.

Draw the front elevation by projecting lines from the various points on the end elevation, and assuming the position of the line *AB* measure off the lengths of the hor. lines and erect their vert. boundaries as shown by the figure.

PROB. 37.—Given the end elevation of the last prob., cut by three planes *A*, *B* and *C*, Fig. 166. Draw the projections of these sections when the part to the left of the cutting plane has been removed, and what remains is viewed in the direction of the arrow, remembering that all the visual rays are parallel.

These drawings and all that may follow are to be properly shade-lined in accordance with the principles given above.

ISOMETRICAL DRAWING.

In orthographic projection it is necessary to a correct understanding of an object to have at least two views, a front and end elevation, or an elevation and plan, and sometimes even three views are required.

Isometric drawing on the other hand shows an object completely with only one view. It is a very convenient system for the workshop. Davidson in his *Projection* calls it the " Perspective of the Workshop." It is more useful than perspective for a working drawing, because, as its name implies ("equal measures") it can be made to any scale and measured like an orthographic drawing. It is, however, mainly employed to represent small objects, or large objects drawn to a small scale, whose main lines are at right angles to each other.

The principles of isometrical drawing are founded on a cube resting on its lower front corner, 1, Fig. 167, and its base elevated so that its diagonal *AB* is parallel to the horizontal plane. Then if the cube is rotated on the corner 1 until the diagonal *AB* is at right angles to the vert. plane, i.e., through an angle of 90°, the front elevation will appear as shown at 1, 2, 3, 4, Fig. 167, a regular hexagon.

Now we know that in a regular hexagon, as shown by Fig. 167, the lines 1*A*, *A*3, etc., are all equal, and are easily drawn

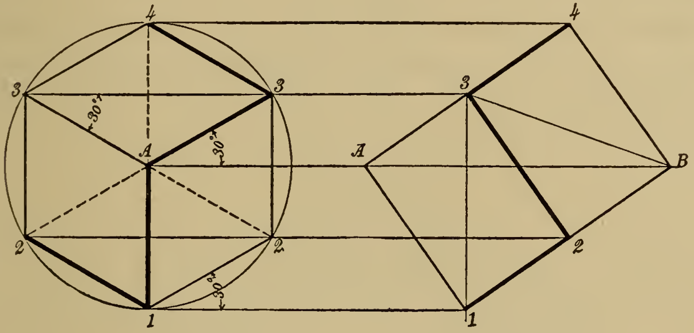


FIG. 167.

with the 30° × 60° triangle. But although these lines and faces appear to be equal, yet, being inclined to the plane of projection, they are shorter than they would actually be on the cube itself. However, since they all bear the same proportion to the original sizes, they can all be measured with the same scale.

We will now describe the method of making an isometrical scale.

Draw the half of a square with sides = $2\frac{1}{2}''$, Fig. 168. These two sides will make the angle of 45° with the horizontal. Now the sides of the corresponding isometrical square, we have seen, make the angle of 30° with the horizontal, so we will draw 1 4, 3 4, making angles of 30° with 1, 3. The difference then between the angle 2, 1, 3 and the angle 4, 1, 3 is 15°, and the proportion of the isometrical projection to the actual object is as the length of the line 3, 2 to the line 3, 4. And if the line 3, 2 be divided into any number of equal parts, and lines be drawn through these divisions par. to 2, 4 to cut the line 3, 4 in corresponding divisions, these will divide 3, 4 proportionately to 3, 2.

Now if the divisions on 3, 2 be taken to represent feet and those on 3, 4 to represent 2 feet, then 3, 4 would be an isometrical scale of ½.

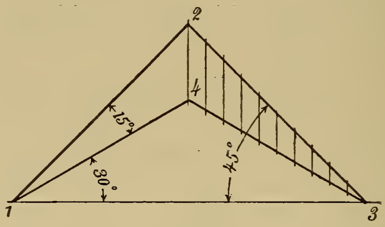


FIG. 168.

Since isometrical drawings may be made to any scale, we may make the isometrical lines of the object = their true size. This is a common practice and precludes the need of a special isometrical scale.

The Direction of the Rays of Light.—The projection of a ray of light in isometrical drawing will make the angle of 30° with the horizontal as shown by the line 3, 2 on the front elevation of the hex., Fig. 167. And the *shade lines* will be applied as in ordinary projection.

PROB. 38.—To make the isometrical drawing of a two-armed cross standing on a square pedestal.

Begin by drawing a center line *AB*, Fig. 169, and from the point *A* draw *AC* and *AD*, making an angle of 30° with the horizontal. Measure from *A* on the center line *AB* a distance = $\frac{5}{16}''$, and draw lines par. to *AC*, *AD*; make *AC* and *AD* $2\frac{5}{8}''$ long and erect a perpendicular at *D* and *C*, completing the two front sides of the base, etc.

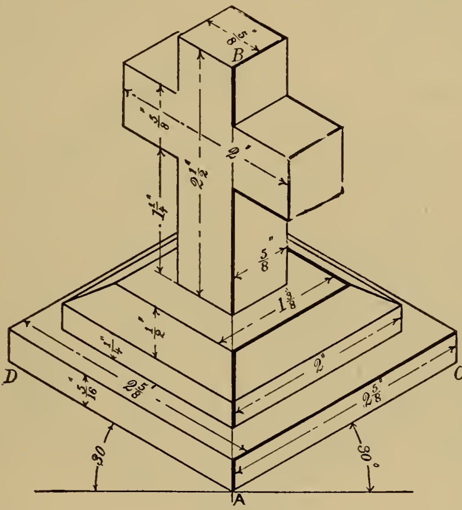


FIG. 169.

PROB. 39.—To make the isometrical drawing of a hollow cube, with square block on each face and a square hole through each block, to dimensions given on Fig. 170.

As before, first draw a center line, and make an isometrical drawing of a $2\frac{1}{2}''$ cube, and upon each face of it build the blocks with the square holes in them, exactly as shown in Fig. 170.

PROB. 40.—To project an isometrical circle.

The circle is enclosed in a square, as shown by Fig. 171.

Draw the circle with a radius = 2" and describe the square 1, 2, 3, 4 about it.

Draw the diagonals 1, 2, 3, 4 and the diameters 5, 6, 7, 8 at right angles to each other.

Now from the points 1 and 2 draw lines 1*A*, 1*B* and 2*A*, 2*B*, making angles of 30° with the hor. diagonal 1, 2. And through the center *O* draw *CD* and *EF* at right angles to the isometrical square.

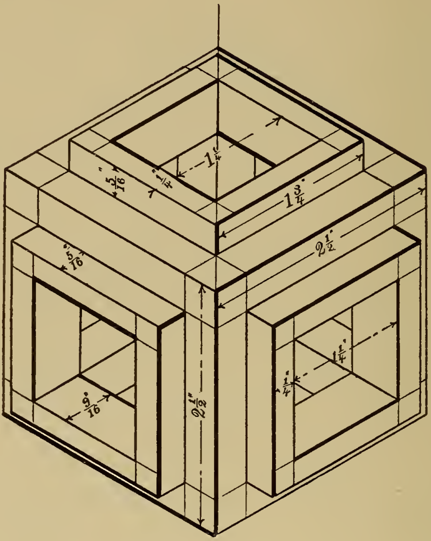


FIG. 170.

The points *CD*, *EF*, and *GH* will be points in the curve of the projected isometrical circle, which will be an ellipse.

The ellipse may be drawn sufficiently accurate as follows:

With center *B* and radius *BC* describe the arc *CF* and extend it a little beyond the points *C* and *F*, and with center *A* and same rad. describe a similar arc, then with a rad. which

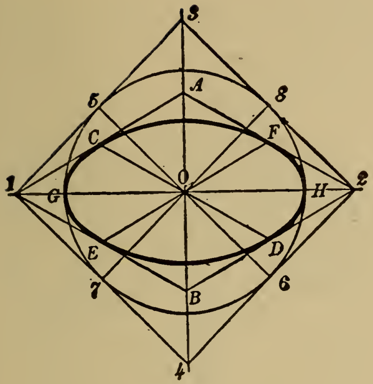

3
A
5
8
C
F
1
O
G
H
2
E
D
7
6
B
4

FIG. 171.

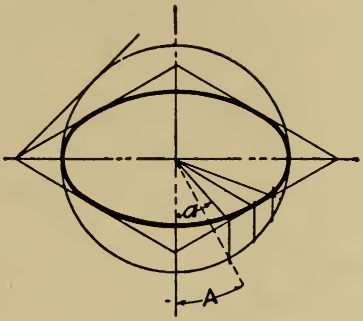


FIG. 172.

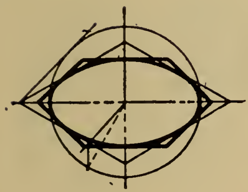


FIG. 173.

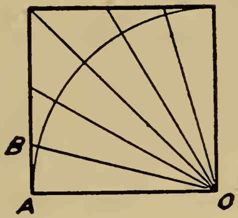


FIG. 174.

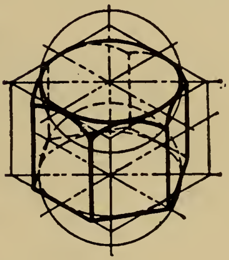


FIG. 175.

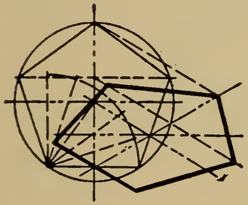


FIG. 176.

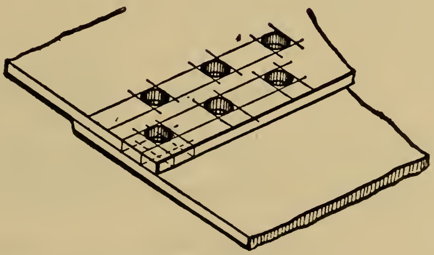


FIG. 177.

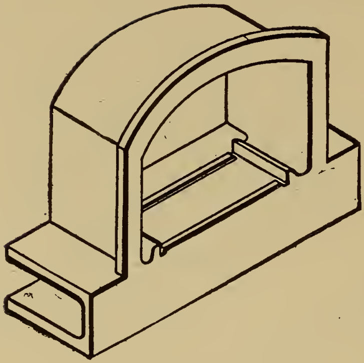


Fig. 178.

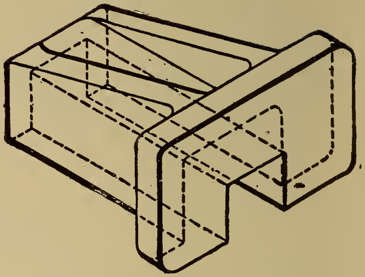


Fig. 179.

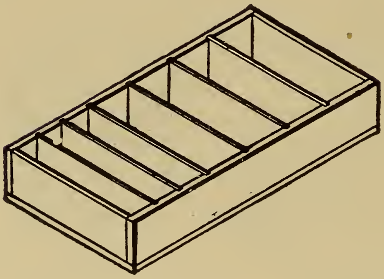


Fig. 180.

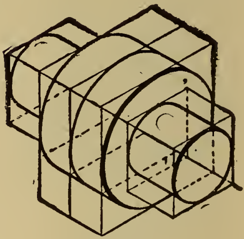


Fig. 181.

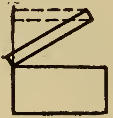


Fig. 182.

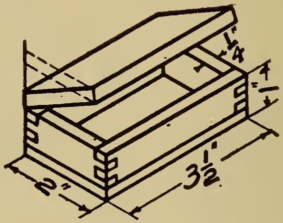


Fig. 183.

may readily be found by trial, draw arcs through the points *G* and *H* and tangent to the two arcs already described.

PROB. 41.—To lay off an angle from a corner of the isometrical cube.

Construct an orthographic square of any convenient size as shown in Fig. 174, and draw the required angle *AOB*. From the corner of the isometrical cube where the angle is to be drawn lay off along the side a distance equal to *OA* of the orthographic square and erect a perpendicular at *A*. Step off the distance *AB* and draw *OB* the angle required. Any other angle may be drawn in similar manner.

Figs. 177, 178, 179, 180, 181, and 184 are for practice in the application of the preceding principles, and at least one of these should be drawn, or it would be better still if the student would attempt to make an isometrical projection of his instrument-box, desk, or any familiar object at hand. These figures may be measured with the 1½″ scale and drawn with the 2″ scale.

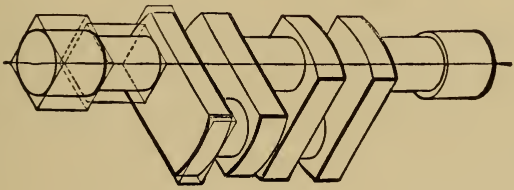


FIG. 184.

WORKING DRAWINGS.

Working drawings are sometimes made on brown detail-paper in pencil, traced on tracing-paper or cloth, and then blue-printed.

The latter process is accomplished as follows:

The tracing is placed face down on the glass in the printing-frame, and the prepared paper is placed behind it, with the sensitized surface in contact with the back of the tracing.

In printing from a negative the sensitized surface of the prepared paper is placed in contact with the film side of the negative, and the face is exposed to the light.

The blue-print system is almost universal in its application to shop drawings, as evidenced in the report on "Conventions" found at page 247.

A Working Drawing in the hands of an experienced workman is intended to convey to him all the necessary information as to shape, size, material, finish, etc., of a machine or other object that will enable him to properly construct it without any additional instructions. This means that it must have a sufficient number of elevations, sections, and plans to thoroughly explain and describe the object in every particular. And these views should be completely and conveniently dimensioned. The dimensions on the drawing must of course give the sizes to which the object is to be made, without reference to the scale to which it may be drawn. The title of a working drawing should be as brief as possible, and not very large—a neat, plain, free-hand printed letter is best for this purpose.

Finished parts are usually indicated by the letter "f," and if it is all to be finished, then below the title it is customary to write or print "finished all over."

Working drawings may be divided into three general types, viz.: General Plans, Machine Drawings, and Patent Office Drawings.

General Plans consists of foundation drawings, piping drawings, layout drawings, maps, etc.

Machine drawings include assembly drawings, detail drawings, diagram and kinematic drawings, sketches and scheming sheets.

Patent Office drawings must conform to the requirements of the U. S. Patent Office as published in the "Official Rules of Practice." They are generally made on two sheet white bristol board with black ink. Size of sheet 10″×15″ with a one inch margin all around. From the top border line of one of the narrow edges $1\frac{1}{4}''$ at least should be reserved for title, number and date. The signatures of inventor, attorney, and witnesses must be placed at the bottom of the sheet inside the border line.

COURSE I.

PROBLEMS IN MECHANICAL DRAWING

INCLUDING

LETTERING, GEOMETRICAL DRAWING, ORTHOGRAPHIC PROJECTION, DEVELOPMENTS, INTERSECTIONS, AND ISOMETRICAL DRAWING.

COURSE I.

MECHANICAL DRAWING.

MINIMUM NUMBER OF PLATES AND MAXIMUM NUMBER OF HOURS ALLOWED TO COMPLETE EACH DIVISION OF THE WORK.

NOTE. Registered freshmen conditioned in Mechanical Drawing will be required to complete satisfactorily the following plates in Courses I and II. In Course I, plates 1 to 6*a* inclusive, also 10, 11, 12, 14, 17, 19, and 21 (58 hours). In Course II, plates 22, 23, 24, 32, 33, 34 and 35 (122 hours).

Students conditioned in Mechanical Drawing must work at least 6 hours per week.

FIRST SEMESTER.

PLATES 1 to 6*a* inclusive, Freehand Lettering, to be handed in on or before Wednesday, Oct. 20, 1909. (28 hours.)

PLATES 7 to 10 inclusive, Geometrical Drawing, to be handed in on or before Wednesday, Nov. 26, 1909. (22 hours.)

PLATES 11 to 13 inclusive, Orthographic Projection, to be handed in on or before Friday, Jan. 29, 1910. (24 hours.)

Total, 74 hours.

Students failing to finish any of the divisions within the specified time for excusable reasons may make arrangements with the Instructor to work in one or more extra periods.

SECOND SEMESTER.

Begins Jan. 24, 1910.

PLATES 14 to 16 inclusive, to be handed in on or before Friday, March 4, 1910. (20 hours.)

PLATES 17 and 18, Developments, to be handed in not later than Friday, April 1, 1910. (16 hours.)

PLATES 19 and 20, Intersections, to be handed in on or before Friday, April 29, 1910. (16 hours.)

PLATE 21, Isometrical Drawing, to be handed in on or before Friday, May 20, 1910. (12 hours.)

Total, 64 hours.

Total number of hours in first and second semesters, 138 hours.

Students failing to complete any of the divisions in the course in this semester within the specified time for excusable reasons may make arrangements with the Instructor to work in one or more extra periods.

Students doing more than the required number of plates in the given time will receive a higher mark, other things being equal.

END OF SECOND SEMESTER.

DIRECTIONS TO BE CAREFULLY OBSERVED WHEN COMMENCING WORK IN MECHANICAL DRAWING.

STUDENTS' CONDUCT IN CLASS.

Students will be expected to give strict attention to their *lettering* or drawing work during the *full* time of each drawing period. Materials and instruments must not be put away until the warning bell rings.

Nothing should be brought to the drawing table that is not needed for the drawing work in hand.

If a student expects to be absent from any regular period he should endeavor to get excused by the Instructor and make arrangements for making up the work.

A student coming late to class should report at *once* to the Instructor, otherwise he will be marked with an unexcused absence. A report from the Instructor concerning the *deportment* of each student in class is expected by the Dean every two months.

When a student is absent from class through an unforseen cause he should at the next regular period fill out an absence blank, giving date and cause of absence, sign it, and hand to Instructor. The work of all absent periods must be made up by arrangement with the Instructor.

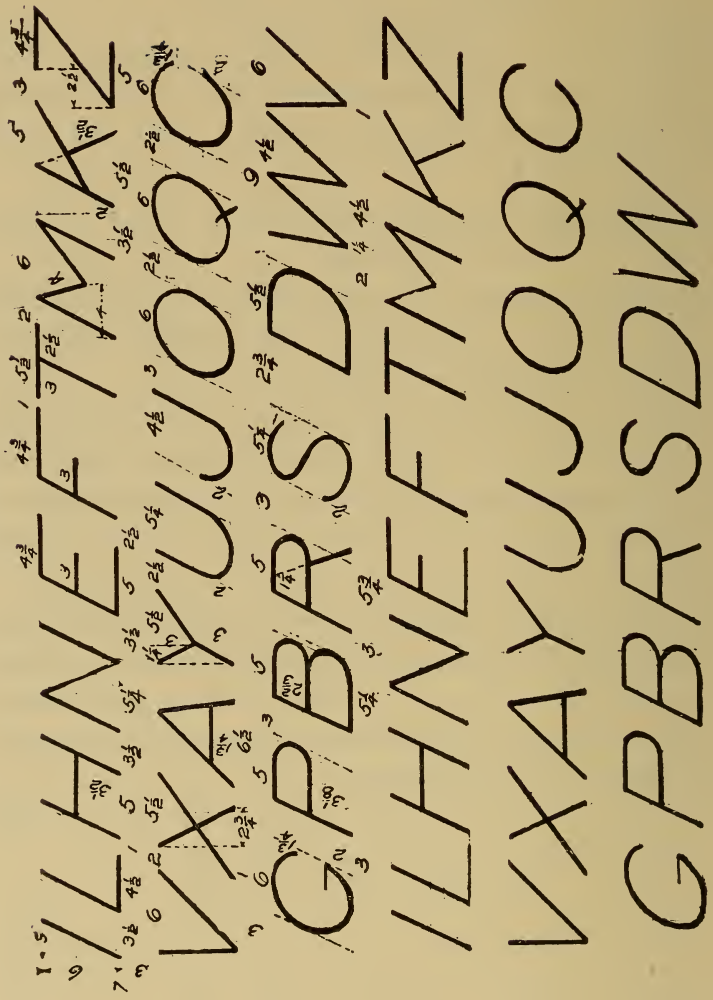
PLATE 1. *Freehand Lettering*, Fig. 185, page 138.—Use the 4 H pencil sharpened to a long conical point, not too sharp.

Locate the *lower* point of the first guide-line 12 squares from top and 7 squares from left-hand edge of cross-section pad.

Guide-lines should be sketched lightly with a downward stroke and allowed to remain until letters are approved.

After drawing the guide-lines for the *curved* letters, analyze the lines of each curved letter, as given on the *chart*

PLATE I.

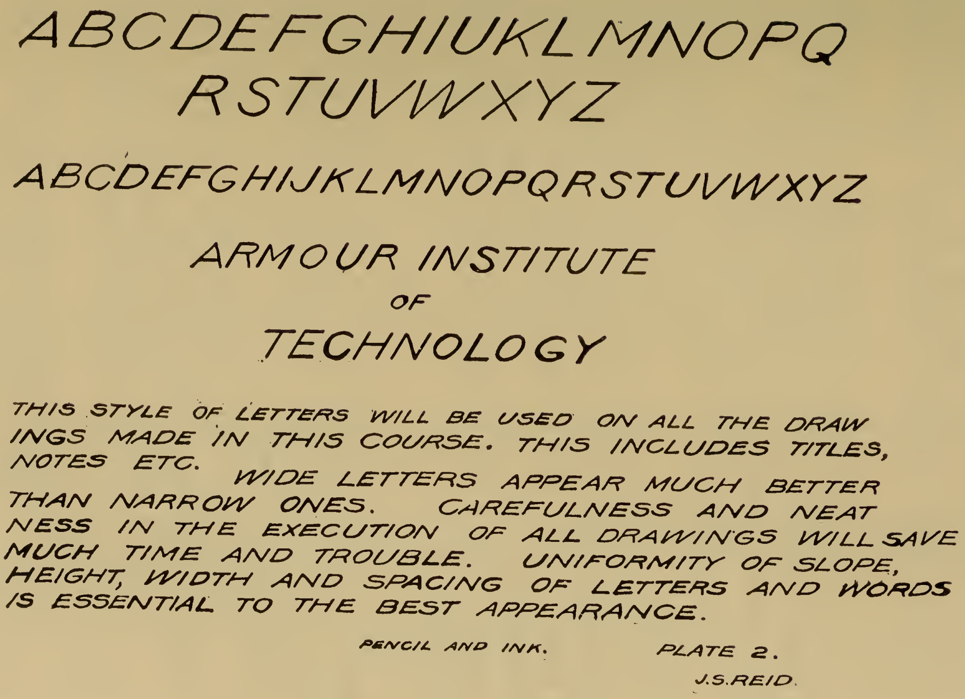


J.S.R.

TO BE PENCILLED ONLY.

FIG. 185.

PLATE 2.



ABCDEFGHIJKLMNOPQ
RSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ

ARMOUR INSTITUTE
OF
TECHNOLOGY

THIS STYLE OF LETTERS WILL BE USED ON ALL THE DRAWINGS MADE IN THIS COURSE. THIS INCLUDES TITLES, NOTES ETC. WIDE LETTERS APPEAR MUCH BETTER THAN NARROW ONES. CAREFULNESS AND NEATNESS IN THE EXECUTION OF ALL DRAWINGS WILL SAVE MUCH TIME AND TROUBLE. UNIFORMITY OF SLOPE, HEIGHT, WIDTH AND SPACING OF LETTERS AND WORDS IS ESSENTIAL TO THE BEST APPEARANCE.

PENCIL AND INK. PLATE 2.

J.S.REID.

Fig. 186.

on the blackboard before attempting to draw the curves on the pad. A very close approximation of the first curved letter as it appears on the *chart* should be obtained before attempting to draw the second curved letter.

Do not copy the letters or figures on pages 138 and 142, the correct form and proportions for all the letters and figures must be obtained by a careful study of the *chart*.

The *work* on all the letters and figures must be *strictly freehand*.

Place at the bottom of each plate at the right-hand corner the following information: *Plate* number, *Section* (days and hours), *Time* taken to finish plate, and *Name*, e.g., MON. and WED., 2–4, *Plate* 1. *Time*, 4 *hours*, *Name*. The height of these letters should be *one* square high and all capitals

PLATE 2. *Freehand* guide lines must be drawn for all letters and figures higher than one square and allowed to remain until letters are approved.

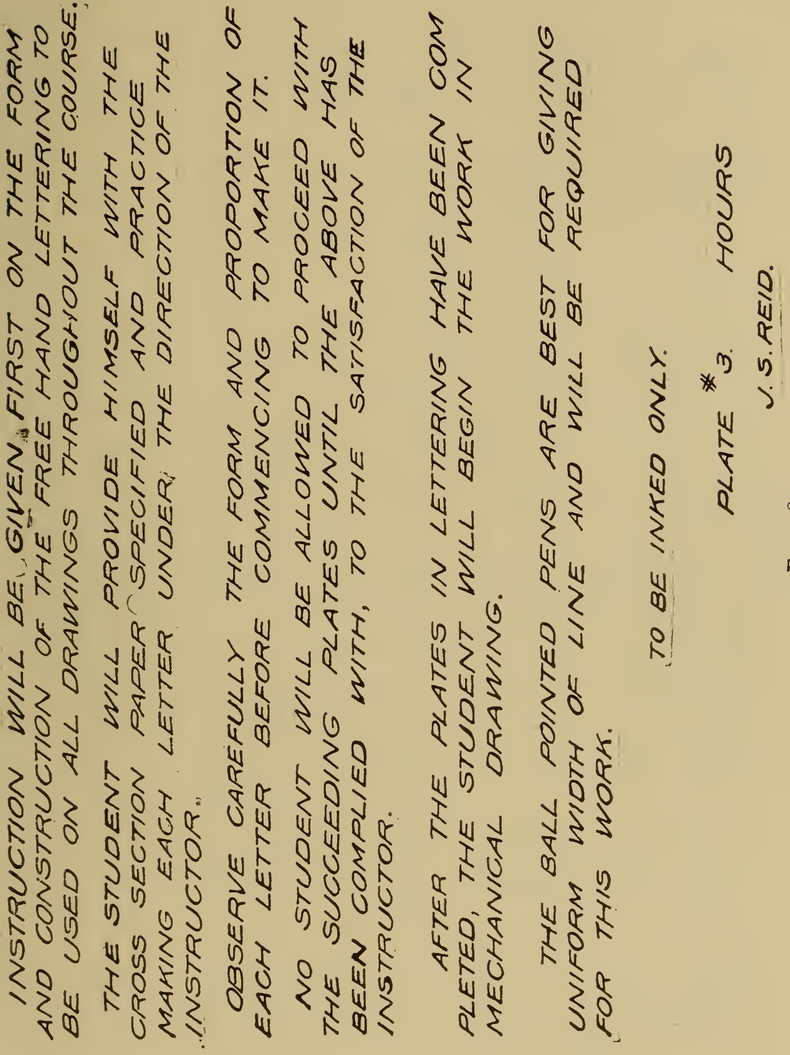
The same care as to *proportion* and *form* should be observed in lettering this plate as in Plate 1.

Be careful to *balance* letters and numbers on all plates so that the same space will appear from both ends of line to edge of pad.

The small letters should be *extended* in width a little beyond the proportion given for the larger letters.

The *open* letters should be spaced closely together and *words* should have a liberal space between them, say 1½ squares.

PLATE 3.



INSTRUCTION WILL BE GIVEN FIRST ON THE FORM AND CONSTRUCTION OF THE FREE HAND LETTERING TO BE USED ON ALL DRAWINGS THROUGHOUT THE COURSE.

THE STUDENT WILL PROVIDE HIMSELF WITH THE CROSS SECTION PAPER SPECIFIED AND PRACTICE MAKING EACH LETTER UNDER THE DIRECTION OF THE INSTRUCTOR.

OBSERVE CAREFULLY THE FORM AND PROPORTION OF EACH LETTER BEFORE COMMENCING TO MAKE IT.

NO STUDENT WILL BE ALLOWED TO PROCEED WITH THE SUCCEEDING PLATES UNTIL THE ABOVE HAS BEEN COMPLIED WITH, TO THE SATISFACTION OF THE INSTRUCTOR.

AFTER THE PLATES IN LETTERING HAVE BEEN COMPLETED, THE STUDENT WILL BEGIN THE WORK IN MECHANICAL DRAWING.

THE BALL POINTED PENS ARE BEST FOR GIVING UNIFORM WIDTH OF LINE AND WILL BE REQUIRED FOR THIS WORK.

TO BE INKED ONLY.

PLATE #3. HOURS

J. S. REID.

Fig. 187.

PLATE 4.

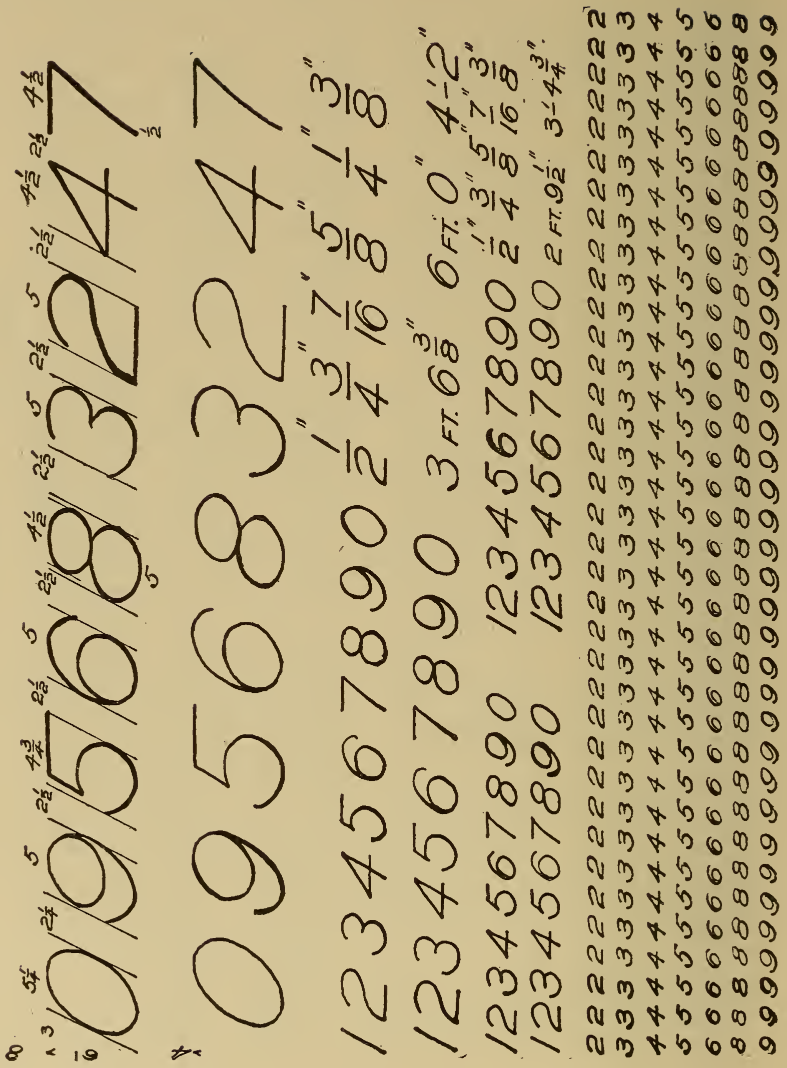

0 9 5 6 8 3 2 4 7
0 9 5 6 8 3 2 4 7
1234567890 1/2" 3/4" 7/16' 5/8" 1/4' 3/8"
1234567890 3 FT. 6 3/8" 6 FT. 0" 4'-2"
1234567890 1234567890 1/2" 3/4" 5/8" 7/16" 3/8"
1234567890 1234567890 2 FT. 9 1/2" 3'-4 3/4"

FIG. 188.

Pencil three words only of the small letters at first and submit for criticism before going on with the others.

Use *Ball* pen, No. 506, to ink large letters and No. 516 for small letters and figures.

PLATES 3–6.—In the next three *letter plates* the directions for *guide-lines*, *form*, *slope*, *spacing* of letters, and for *width* of small letters should be carefully observed.

PLATE 6.* While a substantial majority of the leading drafting rooms in the United States are in favor of using Gothic Capitals exclusively for notes and titles, there are a number using a combination of Gothic Capitals and Lower Case letters. So it is deemed wise to introduce one plate of Lower Case letters to give the student some knowledge of their form, proportion and construction.

This plate should first be pencilled and after approval, inked. In addition to the "Ball" pen, No. 516, for large letters, the small letters should be inked with Gillott's No. 303. All pens when new should be "exercised" a little before beginning to letter. The form and proportion of these letters as given by the largest letters in Fig. 190, on page 145, should be adhered to as closely as possible.

In general these letters should be made with down strokes of a uniform pressure. The only exceptions are the letters *r*

---

* All letters and figures should have uniform slope. Letters and figures of one square high should have a full half square slope.

Each *plate* must be signed by Instructor in charge, in pencil before inking and in ink when plate is finished. Plates not so signed will be rejected.

When plates are finished and signed they will be retained by the student until the six plates on *lettering* are completed, when they are to be bound with paper binders and handed to the Instructor.

PLATE 5.

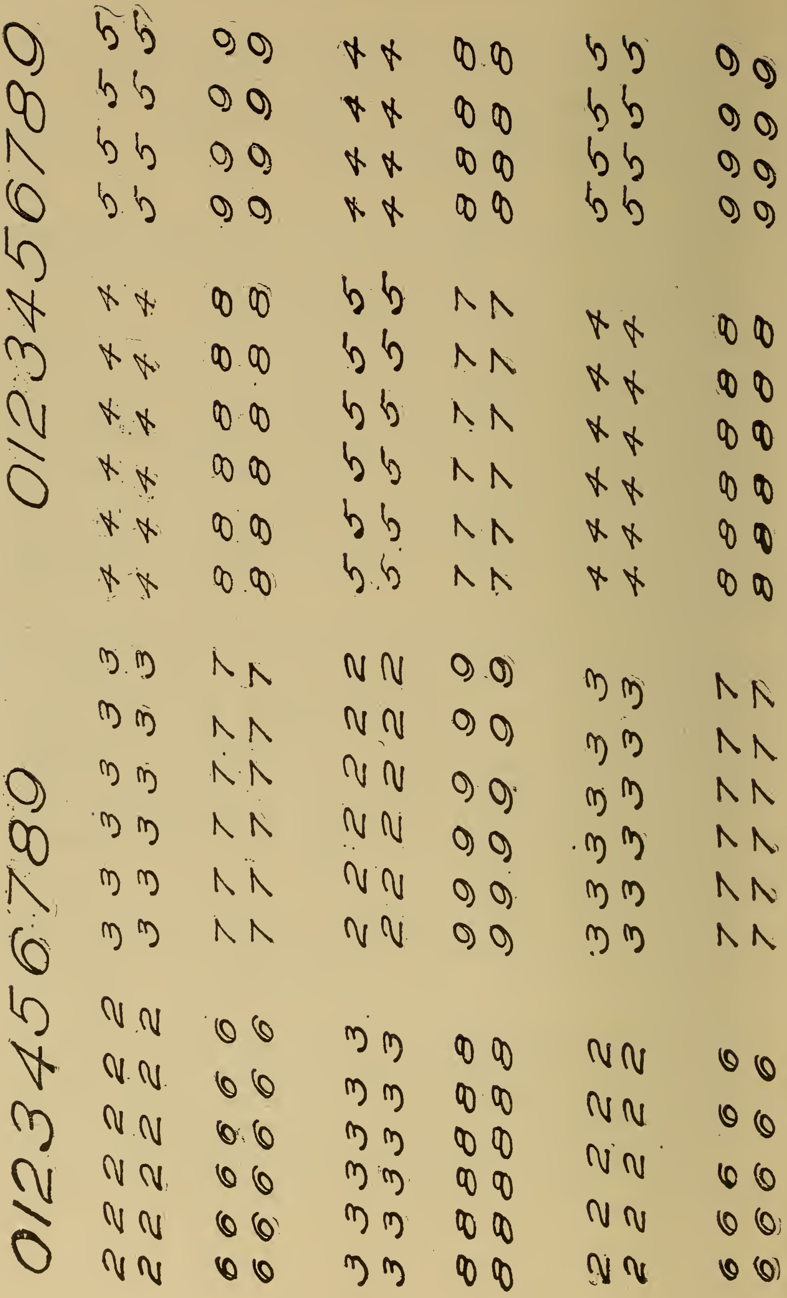
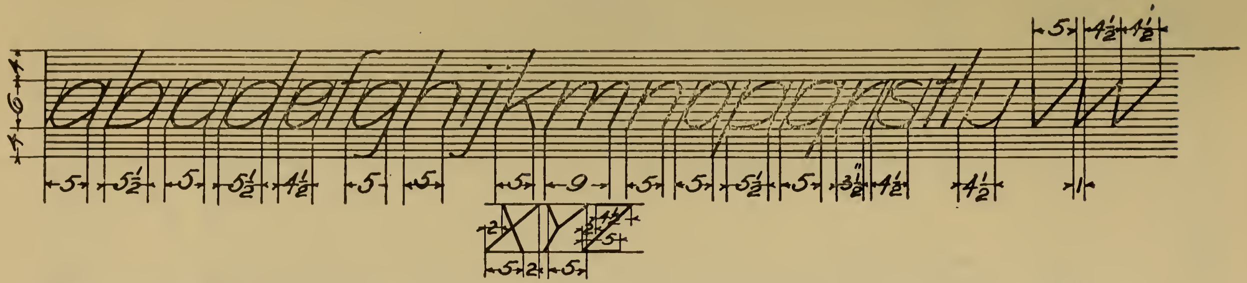

0123456789
0123456789

FIG. 189.

PLATE 6.


abcdefghijklmnopqrstuvw
XYZ
4
6
4
5
5½
5
5½
4½
5
5
5
9
5
5
5½
5
3½
4½
4½
1
5
4½
4½
2
4½
5
5
2
5

The slope for lower case letters is the same as for the capitals, one to two.

In general this style is for everything not covered by style one, and consists of capital letters one eighth of one inch high, and small letters three thirty seconds of an inch high.

All lettering must be freehand. Great care should be taken to make all lettering very neatly and with a maximum of distinctness

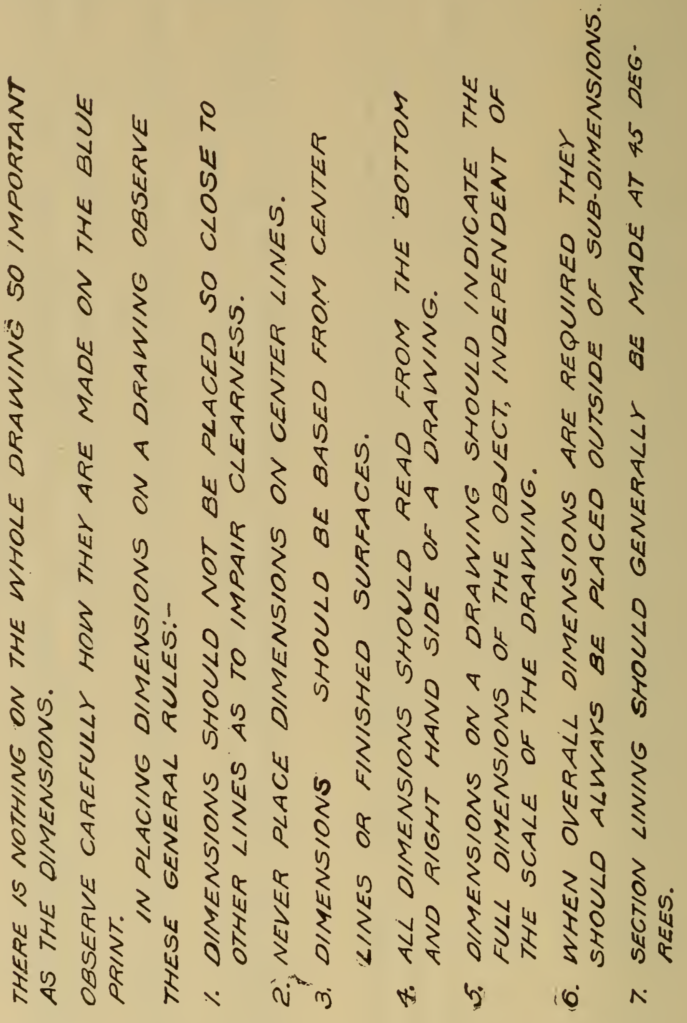
Uniformity in slope and height is essential to the best results

That each student may be able to work most effeciently with out undue fatigue, each should avoid disturbing the other in any way.

Fig. 190.

and *u*. The curved part of the *r* imay be made with an up stroke curved only at the top. The *u* is made with two down strokes

PLATE 6A.



THERE IS NOTHING ON THE WHOLE DRAWING SO IMPORTANT AS THE DIMENSIONS.

OBSERVE CAREFULLY HOW THEY ARE MADE ON THE BLUE PRINT.

IN PLACING DIMENSIONS ON A DRAWING OBSERVE THESE GENERAL RULES:–

1. DIMENSIONS SHOULD NOT BE PLACED SO CLOSE TO OTHER LINES AS TO IMPAIR CLEARNESS.
2. NEVER PLACE DIMENSIONS ON CENTER LINES.
3. DIMENSIONS SHOULD BE BASED FROM CENTER LINES OR FINISHED SURFACES.
4. ALL DIMENSIONS SHOULD READ FROM THE BOTTOM AND RIGHT HAND SIDE OF A DRAWING.
5. DIMENSIONS ON A DRAWING SHOULD INDICATE THE FULL DIMENSIONS OF THE OBJECT, INDEPENDENT OF THE SCALE OF THE DRAWING.
6. WHEN OVERALL DIMENSIONS ARE REQUIRED THEY SHOULD ALWAYS BE PLACED OUTSIDE OF SUB-DIMENSIONS.
7. SECTION LINING SHOULD GENERALLY BE MADE AT 45 DEGREES.

TO BE INKED ONLY.

FIG. 191.

and the bottom curve filled in with a stroke to the right and upward. The *m*, *n*, and *h* should be formed with nearly sharp upper curves.

This plate will have to be repeated until the desired results have been obtained.

PLATE 6*A*, Fig. 191. This is an extra lettering plate for those students who may finish the required plates ahead of time. The extra plate will increase the grade mark.

GEOMETRICAL DRAWING, INCLUDING CONIC SECTIONS; ORTHOGRAPHIC PROJECTIONS; DEVELOPMENTS; INTERSECTIONS; ISOMETRICAL DRAWING, AND ONE WORKING DRAWING.

Before beginning the work in Mechanical Drawing read carefully the directions given on pages 1 to 17. The size of the sheet of cream drawing paper will be 15″×20″. This size will be used for all drawings in mechanical and machine drawing. The border lines and inside divisions will be as shown on page 148, except where otherwise directed.

Use a 6 H pencil sharpened to a long wedge-shaped point, as explained on pages 7 and 8.

The lead in the compasses must also be 6 H and sharpened in the same way. A properly sharpened pencil is necessary to obtain good work.

When the work has been completely pencilled with fine sharp lines it should be submitted to the Instructor for approval and signature, after which the given and required lines of the problem are to be repencilled with a strong, bold line, using a 4 H pencil sharpened to a conical point (not too sharp).

TITLE. The form of title shown in Fig. 192 will be used on all drawings and should be pencilled and inked together with the border lines whether the drawing is to be inked or not. All drawings are to be *finished pencil* drawings, as directed above, except where otherwise stated.

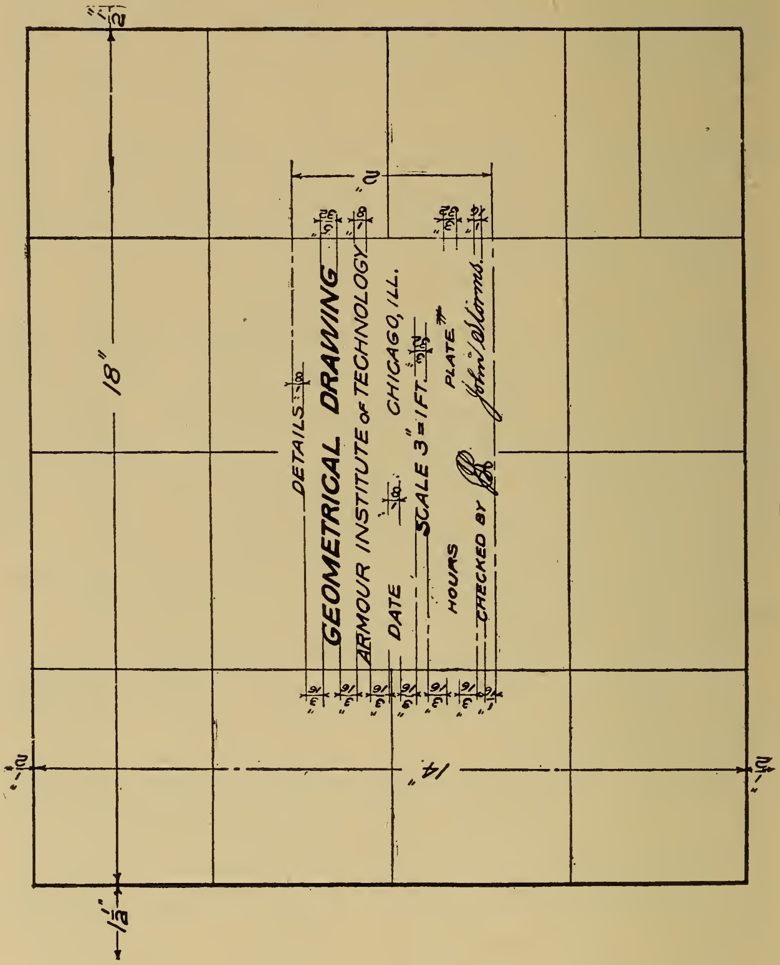

½"
18"
14"
½"
2"
DETAILS
GEOMETRICAL DRAWING
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.
DATE
SCALE 3" = 1 FT.
PLATE #
HOURS
CHECKED BY
3/16"
1/8"

FIG. 192.

Following is a list of the problems to be drawn on each plate:

PLATE 7. (Pages 17 to 26 inclusive.)

Problems 1, 2, 3, 5, 6, 7, 9, 11, 13, 14, 15, 16, 18, 19, and 20. Make the dimensions for each problem to suit the given space so as to comfortably fill it without crowding.

PLATE 8. (Pages 26 to 35.)

Problems 21, 22, 24, 25, 26, 29, 30, 34, 35, 37, 39, 40, 41, 42, and 44.

PLATE 9. (Pages 43 to 53.)

Problems 54, 56, 57, 58, 59. Use four spaces for problem 59; 70, 71, 72 and 73 in one space each, 63 in two spaces, and 94 in one space.

PLATE 10. (Pages 39 to 43.)

Conic Sections. Divide the plate into nine equal spaces. Draw problems 47 and 48 (in problem 48 draw complete upper half of ellipse and draw lower half by "Honey's method," problem 46), 49, 50, 51, 52, 53, and 55. Make twice the size given in the figures.

PLATE 11. (Study pages 74 to 89.)

Orthographic Projection. Divide sheet into nine equal spaces, as shown in Fig. 193, page 150.

Problem 1 shows three views of a wedge-shaped solid, viz., the vertical, horizontal, and profile projections. The vertical projection is commonly termed the "Elevation" or "Front Elevation;" the horizontal projection is generally called the "plan," and the profile projection is known as the "End Elevation" or "End View."

It will be seen that the end view is obtained by revolving points projected from the plane to the profile plane through an

PLATE 11.

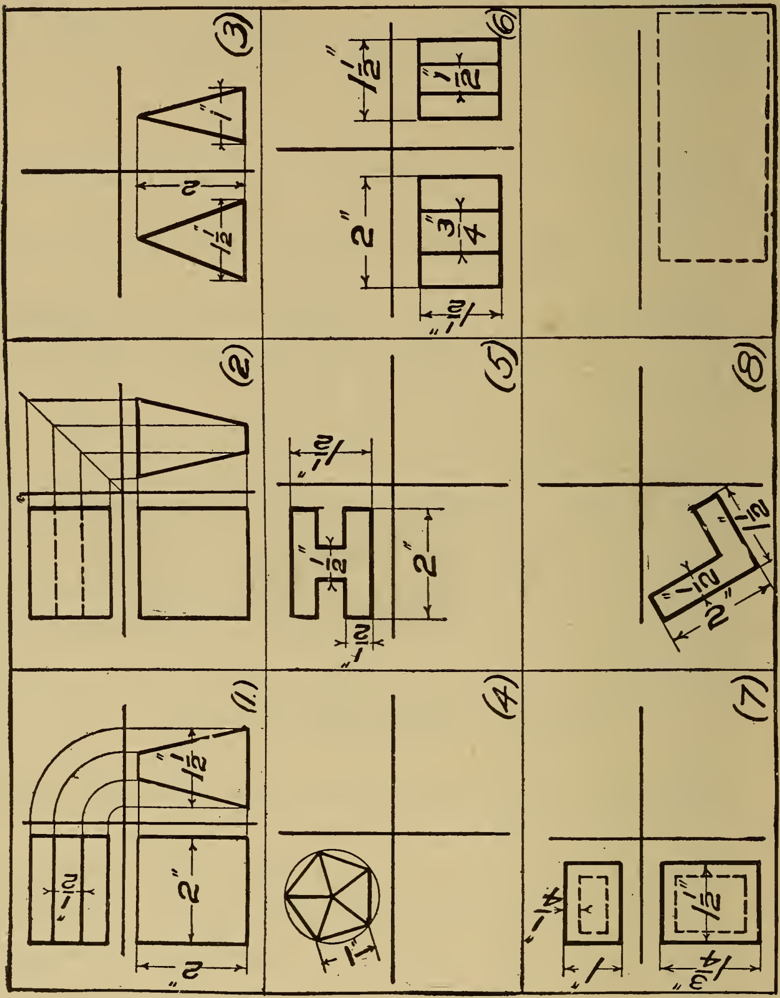

(1)
2"
2"
1/2"
1 1/2"
(2)
(3)
2"
1/2"
1"
(4)
1"
(5)
1 1/2"
1/2"
2"
1/2"
(6)
1 1/2"
1/2"
2"
3/4"
1 1/2"
(7)
1 1/4"
1"
1 3/4"
1/2"
(8)
1/2"
1/2"
2"

FIG. 193.

angle of 90° by means of arcs of circles and dropping perpendiculars to intersect horizontals from the same points in the elevation.

Problem 2. This is the same solid placed differently and having the end view projected by straight lines instead of by arcs of circles. This method will be adhered to in preference to the other, as it takes less time.

Problem 3. Given the front and end sections of a rectangular pyramid 1½″ wide × 1″ thick × 2″ high. From the given views draw the plan.

Problem 4. Given the plan of a pentagonal pyramid whose side is 1″, project the front and end elevations.

Problem 5. Given the plan of an H-shaped block 2″ high, draw front and end elevations.

Problem 6. Given the elevations of a +-shaped block, draw the plan.

Problem 7. Given front elevation and plan of a hollow rectangular prism, draw the end elevation.

Problem 8. Given the front elevation of an L-shaped block 2″ long, draw the end elevation and plan. In the title of this sheet leave out the word "Details" and make title *name* "Orthographic Projection."

PLATE 12.

Problem 1. Given the elevation and plan of a 1½″ square pyramid 1¾″ high, draw the end view.

Problem 2. Given the same pyramid of problem 1 when the plan has been rotated to the left through an angle of 15°. Project the front and end elevations.

Problem 3. Given the front elevation of the figure obtained in problem 2 when revolved to the left through an angle of 15°. Draw the plan and end elevation.

Problem 4. Given the front elevation of problem 1 when revolved through an angle of 30° to the right. Draw the plan and end view.

Problem 5. Given the end elevation of the pyramid obtained in problem 2 when revolved to the right through an angle of 15°. Project the front elevation and plan.

PLATE 12.

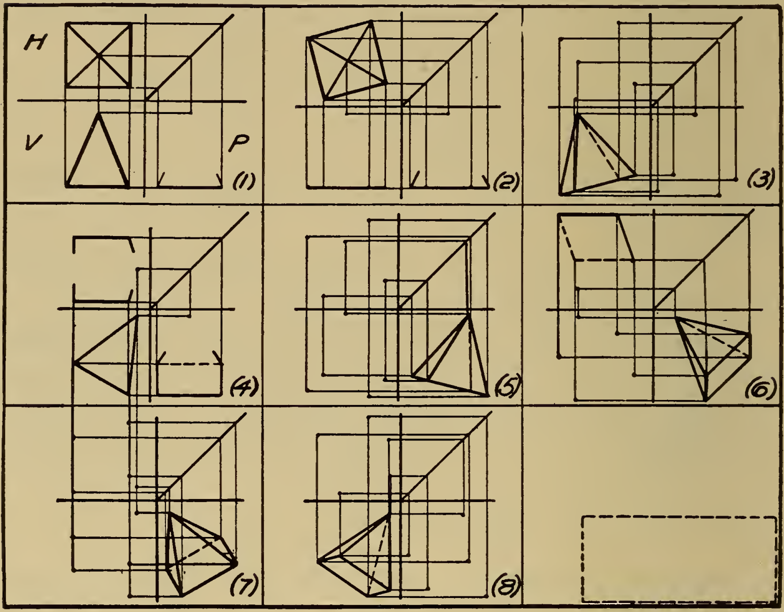


FIG. 194.

Problem 6. Given the end view of the pyramid obtained in problem 3 when revolved to the left through an angle of 45°. Draw the front elevation and plan.

Problem 7. Given the end view of the pyramid obtained in problem 4 when revolved through an angle of 30° to the left. Draw the elevation and plan.

Problem 8. Given the front elevation obtained in problem 5 when revolved 30° to the right. Draw plan and end view. Title similar to that on Plate 11.

PLATE 13.

In the same positions as given above draw the projections of a rectangular prism, Fig. 199, $1\frac{1}{2}'' \times 1'' \times 2''$ high.

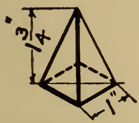


FIG. 195.

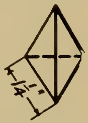


FIG. 196.

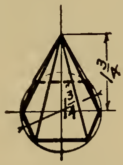


FIG. 197.

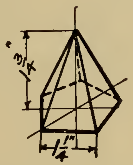


FIG. 198.

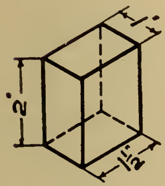


FIG. 199.

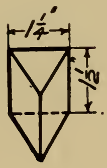


FIG. 200.

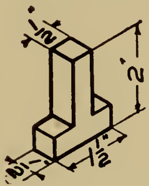


FIG. 201.

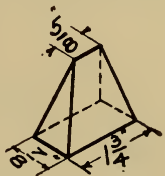


FIG. 202.

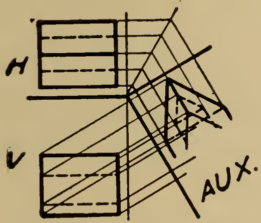


FIG. 203.

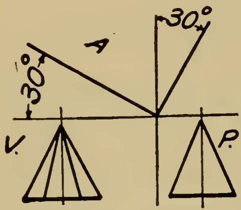


FIG. 204.

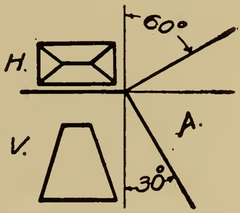


FIG. 205.

PLATE 14.

Using same positions as in Plate 12, draw the projections of a hexagonal pyramid, Fig. 197, circumscribed circle of hexagon $= 1\frac{3}{4}''$ diameter, height $1\frac{3}{4}''$.

PLATE 15.

Given a pentagonal pyramid, Fig. 198, whose side is 1¼″, height 1¾″, draw the projections of the various positions as required in Plate 12.

PLATE 15 *B*.

In the same positions as given above draw the projections of a triangular prism, Fig. 200, page 153, side of triangle 1¼″, height of prism 1½″.

PLATE 15 *C*.

In the same positions as given above draw the projections of a T-shaped block, Fig. 201, page 153.

PLATE 15 *D*.

In the same positions as given above draw the projections of a wedge, Fig. 202, page 153. Plates 15 *B*, 15 *C*, 15 *D* are extra plates to be drawn by those who finish the required plates ahead of time.

PLATE 16.

Problem 1. Given the elevation and plan of a hollow triangular prism in the position shown in Fig. 203, page 153. Complete the projection in the auxiliary plane.

Problem 2. Given the elevation and end view of a hexagonal pyramid, draw the projection on the auxiliary plane, shown in Fig. 206, page 153. Use same dimensions given in Fig. 197.

Problem 3. Given the elevation and plan of a wedge, draw the projection on the auxilary plane, shown in Fig. 205*c* page 153. Use same dimensions given in Fig. 202.

Problem 4. Given elevation, plan, and revolved position of plan of a right circular cone, Fig. 212, page 155. Base 3″ diameter, height 3″. Draw elevation and end view in revolved position. See page 88. In planning position of drawings on this plate, locate problems 1, 2, and 3 along the top of the sheet and problem 4 in the lower left hand.

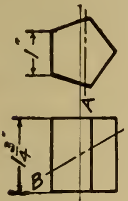


FIG. 206.

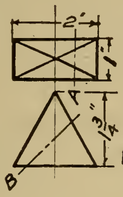


FIG. 207.

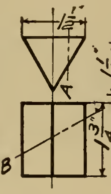


FIG. 208.

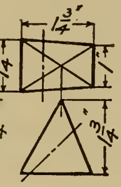


FIG. 209.

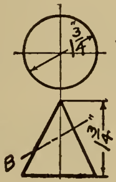


FIG. 210.

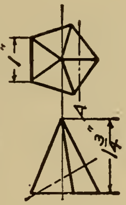


FIG. 211.

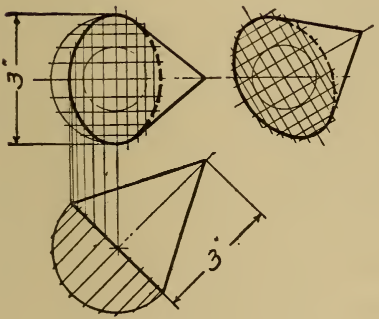


FIG. 212.

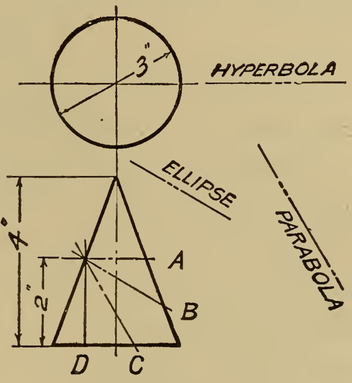


FIG. 213.

PLATE 17. DEVELOPMENTS.

Scheme the layout of all the problems in this plate before beginning to draw.

Problem 1. Given the elevation and plan of a pentagonal prism, Fig. 206, page 155, 1″ side, 1¾″ high, cutting planes *A* and *B*, draw projections as shown in Fig. 125, page 90. Draw the development of the part below the cutting plane *B*. See Fig. 126, page 90.

Problem 2. Given elevation and plan of a rectangular pyramid, Fig. 207, page 155, 2″×1″×1¾″ high, and cutting planes *A* and *B*. Draw projections and developments as required for problem 1.

Problem 3. Given views and cutting planes of equilateral triangular prism shown in Fig. 208, page 155. Draw sections and development.

Problem 4. Given views and cutting planes of pyramid shown in Fig. 209, page 155. Draw sections and development.

In this problem when laying out the development, allowance must be made for the unequal inclined edges of the sides of the pyramid. See Fig. 117, page 82.

PLATE 18.

Problem 1. Given the right circular cône, as shown in Fig. 210, page 155. Draw sectional plan and development.

Problem 2. Given pentagonal pyramid, Fig. 211, page 155, and cutting planes *A* and *B*. Draw sections and development.

Problem 3. Given projections of right circular cone, Fig. 213, page 155, and cutting planes *A*, *B*, *C*, and *D*. Draw the projections of conic sections as indicated by center lines. Draw also development of part of cone below cutting plane *B*. If space will not permit of full development draw half. See Fig. 130, page 95.

PLATE 19. INTERSECTIONS.

Problem 1. Draw three views of two right circular cylinders of equal diameter, shown in Fig. 214, page 157, intersecting at right angles to each other. Draw curve of intersection. See page 96.

Problem 2. Make the drawing shown in Fig. 215, page 157, and draw curve of intersection.

Problem 3. Make drawing shown in Fig. 216, page 157, and project curve of intersection.

Problem 4. Fig. 217, page 157, shows a square prism inter-

FIG. 214.

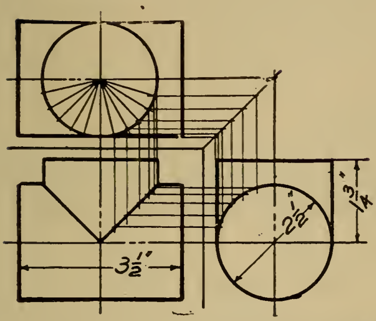
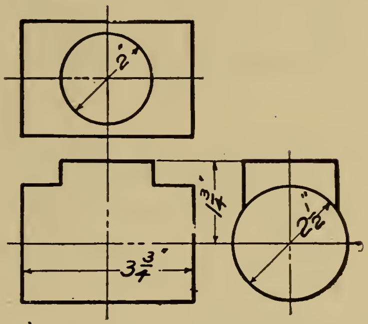


FIG. 215.



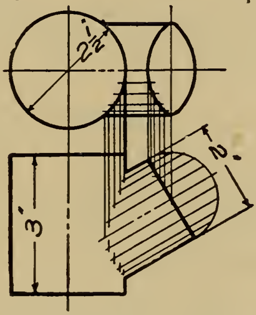


FIG. 216.

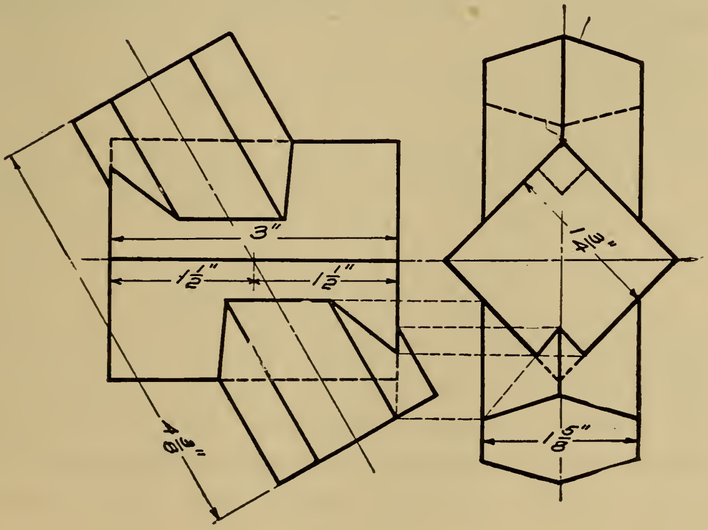


FIG. 217.

sected by a hexagonal prism partly shown in elevation. Complete the elevation and draw also half end view. Total length of hexagonal prism 4⅜″.

Plate 20.

Problems 1 and 2. Construct the curves of intersection shown on the connecting-rod ends in Figs. 140 and 141, page 102, and draw three complete views of each.

Problems 3 and 4. Draw the projections of a "V" and "Square" threaded screw according to directions given on pages 99 and 100, Figs. 137 and 138.

Plate 21. Isometrical Drawing.

See pages 122 and 123.

Problem 1. Make the isometrical drawing of a 2¼″ cube. Draw a 2¼″ isometric circle on the upper face by the method shown in Fig. 171, page 127. From the lower left-hand corner of the right-hand face lay off angles of 15°, 30°, and 45°. Use method shown in Fig. 174, page 127. See problem 41, page 129.

Problem 2. Draw the hollow cube as shown in Fig. 170, page 126, except that instead of the hollow block on the upper face draw a cylinder of 1¾″ diameter and 1″ high.

Problem 3. Make the isometrical drawing of a hexagonal headed bolt, shank 1″ diameter and 2″ long. Head 1″ thick. Use either of the methods shown in Figs. 173 and 175, page 127.

Problem 4. Make the isometrical drawing of a pentagonal prism of 1⅞″ sides and 2½″ high. On the top of the prism draw an isometric circle of 2″ diameter. See Fig. 176, page 127.

Problem 5. Make the isometrical drawing of the tool box shown at Fig. 183, page 128. Dimensions 3½″ long × 2″ wide × 1″ deep, over all. Cover and sides ¼″ thick. Use the method of offsets shown in Fig. 182, page 128. Place full dimensions on this drawing. Plate 21 is to be finished in pencil and inked. See directions for inking with the spring bows on page 14, the large compass on page 13, and the ruling pen on page 9. See also directions given for inking Plate 22 on page 159.

PLATE 22.

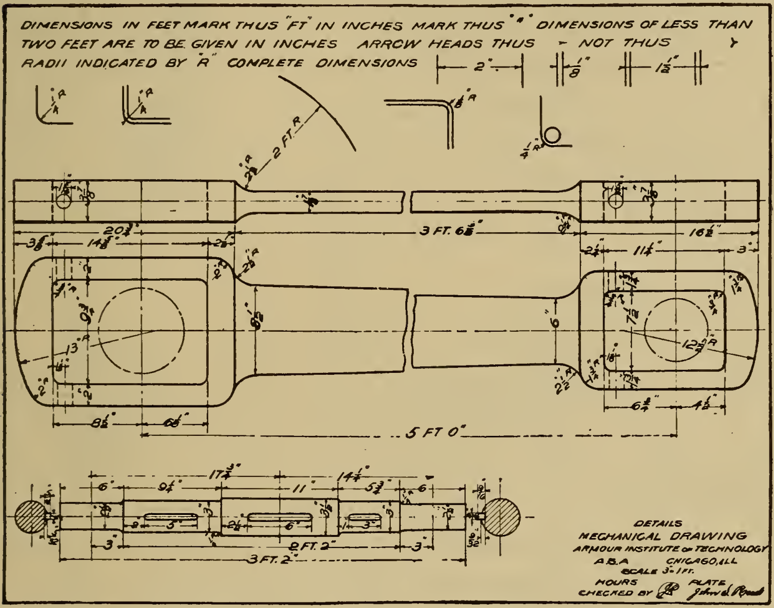

DIMENSIONS IN FEET MARK THUS "FT" IN INCHES MARK THUS " DIMENSIONS OF LESS THAN TWO FEET ARE TO BE GIVEN IN INCHES ARROW HEADS THUS NOT THUS
RADII INDICATED BY "R" COMPLETE DIMENSIONS
2"
1/8"
1 1/2"
2 FT. R
3 FT. 6 1/2"
20 3/4"
14 3/8"
16 1/2"
11 1/4"
12 3/4" R
6 1/4"
4 1/2"
8 1/2"
6 1/2"
5 FT 0"
17 3/4"
14 1/4"
9 1/4"
11"
5 3/4"
2 FT. 2"
3 FT. 2"
DETAILS
MECHANICAL DRAWING
ARMOUR INSTITUTE OF TECHNOLOGY
A.B.A CHICAGO, ILL
SCALE 3"=1 FT.
HOURS PLATE
CHECKED BY
John d. Reed

FIG. 218.

PLATE 22. WORKING DRAWING.

Problems 1 and 2. Make the working drawing of connecting rod and axle shown in Fig. 218, page 159. Begin by laying off the border line and space for title. Draw guide-lines $\frac{1}{8}''$ high and $\frac{1}{4}''$ space between lines. Locate all center lines of rod and axle. Use 6 H pencil sharpened as directed on page 8. Draw fine, clear, clean-cut lines. When drawings of rod and axle

PLATE 22F.

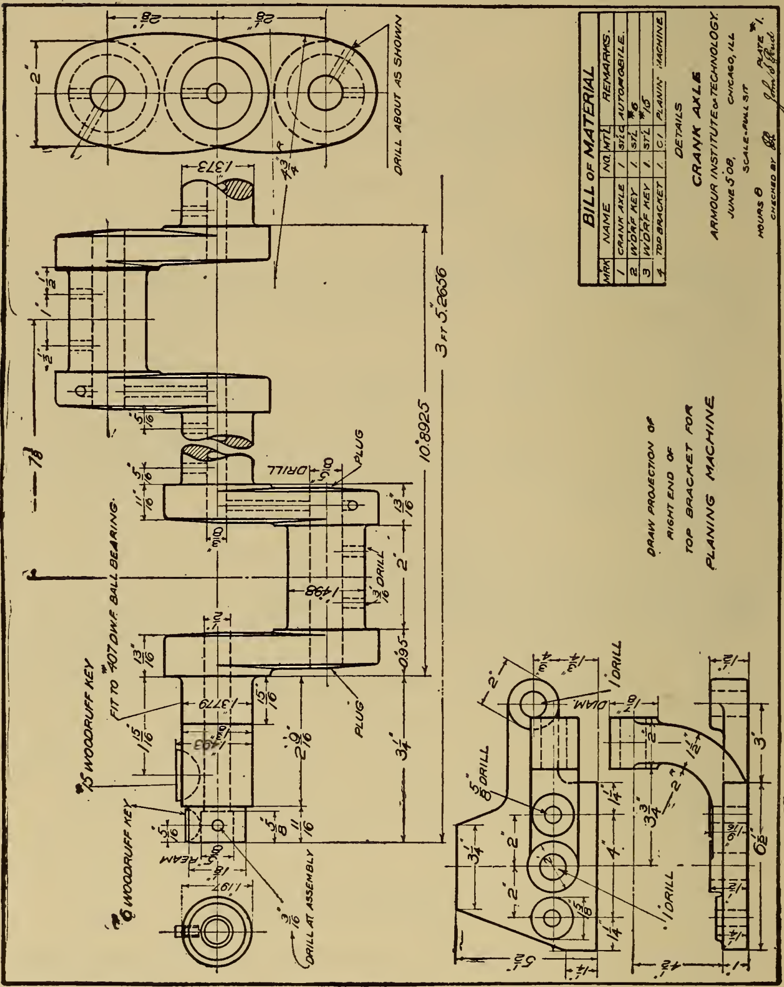

BILL OF MATERIAL
MRK NAME NO. MTL REMARKS.
1 CRANK AXLE 1 STL AUTOMOBILE.
2 WDRF KEY 1 STL #6
3 WDRF KEY 1 STL #15
4 TOP BRACKET 1 C.I. PLANING MACHINE
DETAILS
CRANK AXLE
ARMOUR INSTITUTE OF TECHNOLOGY
DRAW PROJECTION OF RIGHT END OF TOP BRACKET FOR PLANING MACHINE
DRILL ABOUT AS SHOWN
#15 WOODRUFF KEY
FIT TO #407 DWF BALL BEARING
#6 WOODRUFF KEY
DRILL AT ASSEMBLY
PLUG
REAM
DRILL
DIAM.
10.8925
3 FT 5.2656

FIG. 219.

are complete and approved, strengthen the lines with 4 H pencil, conical point. Then draw dimension lines. Next put in arrow-heads and dimensions, beginning at the upper left hand and working down toward the lower right-hand corner.

When the drawing is properly finished in pencil and signed by the Instructor it will be ready for tracing on cloth. Begin the tracing with the spring bow pen. Ink all arcs of circles, circles, and irregular curves before inking any straight lines. Then ink dimension lines. Next ink arrow-heads and dimensions in consecutive order, beginning with the left-hand arrow-head, then dimension, next sign of inches, and then left-hand arrow-head. Ink hatch lines and center lines last of all. For weight and character of lines see Standard Lines on page 247.

PLATE 22 *F*.

Problem 1. Make drawing of automobile crank axle, as shown in Fig. 219, page 160. Use same directions for pencilling and inking as given for Plate 22.

Problem 2. Make drawing of top bracket for planing machine, as shown in Fig. 219, page 160. Project also right end view of bracket. Make finish pencil drawing and trace on cloth.

This plate is not required in the course of mechanical drawing, but credit will be given for it in the Freshman Course to those who may have time to finish it in this course. A higher mark will be given to the student completing this plate in addition to the required plates.

Course I is preparatory to Courses II and III.

Course III is given in "MECHANICAL DRAWING AND ELEMENTARY MACHINE DESIGN," by John S. and D. Reid, John Wiley & Sons, New York.

CHAPTER VI.

ARCHITECTURAL DRAWING.

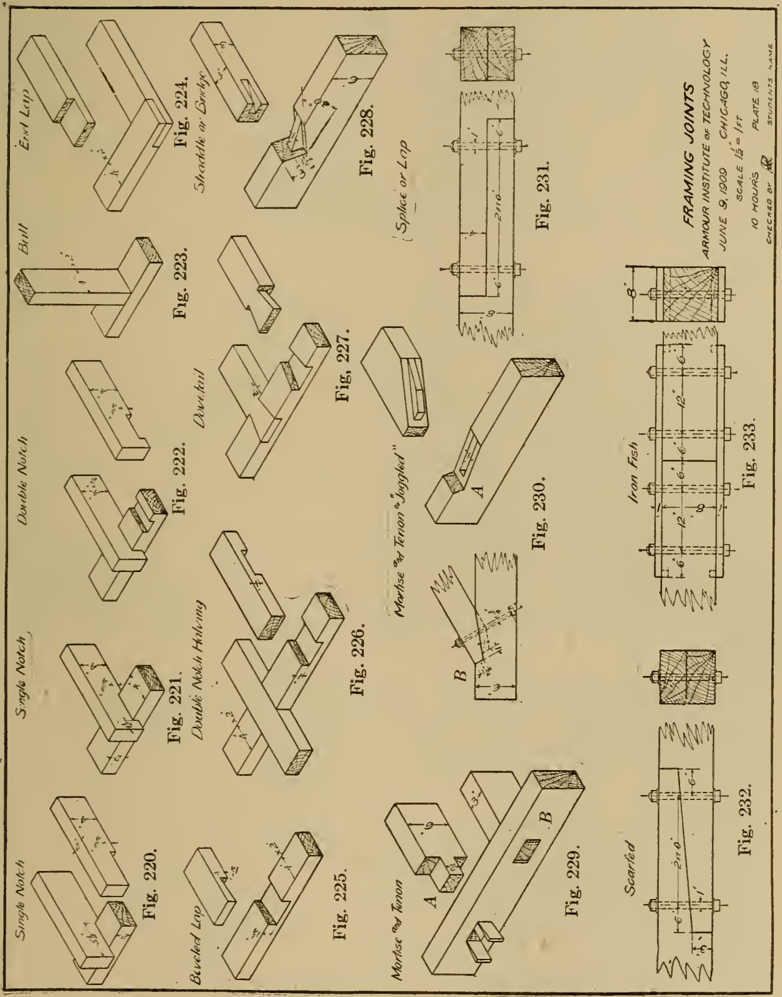
THE method of applying the principles of projection to the making of architectural working drawings is the same as in mechanical or machine drawings, except that third angle projection is used in the latter, while first angle projection is almost invariably used in the former.

The instruments and materials used in architectural drawing are practically the same as for mechanical and machine drawing. There are a few additional materials needed however, in architectural work, viz., a tinting brush, water glass, color saucer, colors, stick of India ink, slate, ink well, and white drawing paper suitable for taking water colors.

While it is true that experienced architectural draftsmen use pencils of a much softer grade than those used by machine draftsmen, it is better for the student while learning to continue the use of the harder grades as required in mechanical drawing.

The following objects which have been selected for problems in architectural drawing in addition to those which have been given before are necessarily limited. They are elementary and preparatory to a larger and more comprehensive course in architectural drafting.

PLATE 23.


Single Notch
Fig. 220.
Single Notch
Fig. 221.
Double Notch
Fig. 222.
Butt
Fig. 223.
End Lap
Fig. 224.
Beveled Lap
Fig. 225.
Double Notch Halving
Fig. 226.
Dovetail
Fig. 227.
Shoulder or Bridge
Fig. 228.
Mortise and Tenon
A
B
Fig. 229.
Mortise and Tenon "Joggled"
B
A
Fig. 230.
Splice or Lap
Fig. 231.
Scarfed
Fig. 232.
Iron Fish
Fig. 233.
FRAMING JOINTS
ARMOUR INSTITUTE OF TECHNOLOGY
JUNE 9, 1900 CHICAGO, ILL.
SCALE 1½" = 1 FT
10 HOURS PLATE 18
CHECKED BY STUDENTS NAME

FRAMING JOINTS.

In elementary building construction, carpenters' joints occupy an important place. The joints are divided into various forms of notches, tenons, and mortises and combinations of the same.

A *Single Notch* is a hollow cut in a board or scantling into which another board is fitted and fastened. Examples of the single and double notches are shown in Figs. 220, 221, and 222, Plate 23.

The *Butt Joint.*—Fig. 223 shows a butt joint where the end of a stud is fastened to a plate without a notch.

End Lap.—Fig. 224 is a special form of double notch usually called *halving*. The boards are of equal thickness and both are notched half their thickness, so that when fastened together they form a smooth flush surface.

Beveled Lap.—Fig. 225 is an example of the lap joint when the notch in both scantlings is beveled with an equal and opposite slope. Fig. 226 shows a lap joint where the pieces cross each other.

Dovetail Halving.—Fig. 227 shows a dovetail lap joint where notches are of such slope that the end cannot be withdrawn.

Mortise and Tenon.—Fig. 229 shows a plain mortise and tenon joint. The tenon, *A*, is the projection on one piece which is made to fit into the mortise shown, cut in the other with two wedges which are driven in when the tenon is in place to tighten it. The *shoulders* of the tenon are shown at its root; the *abutments* of the mortise are the faces on which the shoulders rest; and the cheeks are the two internal faces on which the grain runs lengthwise. The tenon is made one-third the thickness of the scantling. The finished joint is shown at *B*.

PLATE 24.

ENGLISH BOND

BOND is the method of connecting bricks by lapping them over each other in building.

- A.-First course
- B. Second course
- C. Closers
- D Headers
- E. Stretchers
- F. Racking Back
- G. Toothing

Size of bricks 8"x4"x2¼".

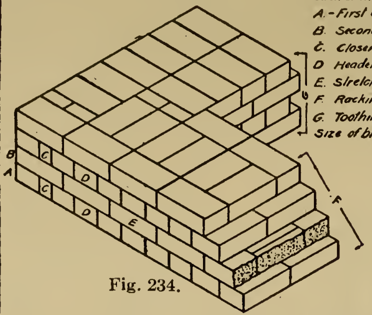


Fig. 234.

SCALE-1½"=1FT.

FLEMISH BOND

Different sizes of bricks used in this country are.-

- East 7¾"x3¾"x2¼"
- Middle States 8"x4"x2¼"
- West. 8¼"x4⅛"x2½"
- Roman 12"x4"x1½"
- Pressed 8⅜"x4⅛"x2⅜"+1½"

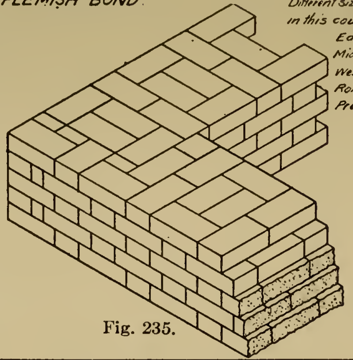
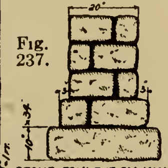


Fig. 235.

SCALE-1½"=1FT.

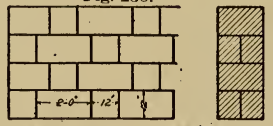
Fig. 237.



STONE FOUNDATION WALL.

SCALE ¾"=1FT.

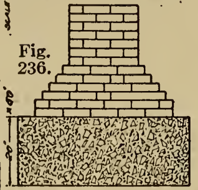
Fig. 238.



REGULAR COURSED MASONRY.

Scale ½"=1Ft.

Fig. 236.



BRICK AND CEMENT FOUNDATION.

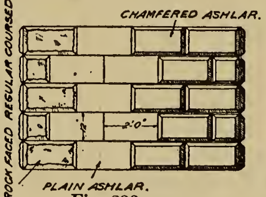
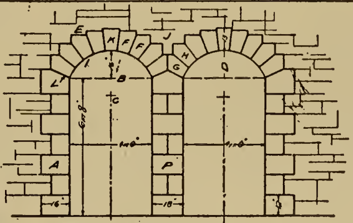

ROCK FACED REGULAR COURSED
CHAMFERED ASHLAR.
PLAIN ASHLAR.
12"
2'0"

Fig. 239.


A
B
C
D
E
F
F
G
H
I
J
K
L
P
6'-8"
4'-0"
4'-0"
16"
18"

STONE SEGMENTAL ARCH.

Fig. 240.

scale ⅜"=1ft.

- A.-Abutment
- B.-Span
- C.-Center
- D.-Rise
- E.-Extrados.
- F.-Vousoirs.
- G.-Springer.
- H.-Haunch
- I.-Intrados
- J.-Spandrel.
- K.-Keystone
- L.-Skewback.
- P.-Pier.

BRICK AND STONE WORK.

Mortise and Tenon Joggled Joint.—This joint, Fig. 230, is a modification of the preceding one to suit the angle at which the timbers are inclined. The left hand end of the tenon is cut square to the plane of the abutment to avoid the sharp end which would tend to shear the timber beyond. The angle at *A* should be a right angle. An orthographic projection of this joint is shown at *B*.

Straddle or *Bridge Joint.*—This joint, Fig. 228, is a reversal of the mortise and tenon joint

Splice or *Lap Joint.*—Fig. 231 shows a simple lap splice used to join two timbers together.

Scarfed Joint.—Fig. 232 shows a scarfed joint to resist cross stress. A fish plate added would strengthen this joint very much. The compression part should have a square abutment as shown, but the tenon part may have a *bird mouth* abutment and sally.

Iron Fish Plate Joint.—Fig. 233 shows the two beams butted end to end, and iron fish plates are bolted on to two opposite sides and sometimes to all sides for compression.

BRICKWORK.

In building a wall with brick the main object is to obtain the greatest strength with the materials used, and at the same time to obtain the most pleasing external appearance. The most important methods used to obtain these results are what is known as the English and Flemish bond. By bond is meant the connection of bricks one with another by lapping them over each other in building.

Fig. 234 is an example in English bond where the courses appear as *heading* and *stretching* courses alternately.

Fig. 235 shows an example of the Flemish bond where the *headers* and *stretchers* alternate in the same course.

Brick and Cement Foundations.—The width of the lowest course of a wall must be such that it will not press in the ground with a greater load per square foot than the ground can safety bear. This is accomplished by what is known at *footings*, whose widths should be apportioned to the weight to be carried, so that there will be a uniform pressure under all parts of the building. An empirical rule is often used which makes the lowest course of the footings twice the width of the wall itself. Footings are always made in English bond, and spread on each side of the wall by one-quarter brick at each off-set. The outer rows should be headers as far as possible.

Concrete is often used nowadays to lessen the pressure per square foot on the earth below. Quite often the footings are dispensed with, and the wall is built directly on the concrete foundation. Fig. 236 shows a sectional elevation of a brick footing with a concrete foundation.

Stone Foundation Wall.—There are three classes of walling, viz., rubble, regular course masonry, and ashlar. A proper bond is always desirable. This is obtained by using headers and stretchers similar to brickwork, but not necessarily so regular. Headers are long stones extending into the wall from either face and reching beyond the middle of the wall.

Fig. 237 gives an example of a stone foundation wall. Fig. 238 regular course masonry, and Fig. 239 rock face, plain and chamfered ashlar.

Fig. 240 shows two segmental arches which have for their intrados segments of circles. The names of the different parts are given on the drawing.

ARCHITECTURAL LETTERING.

More latitude is allowed to the architectural draftsman in his choice of styles of lettering for notes and titles on working drawings than is given to the machine draftsman. The latter is required to use that style of letter which gives the neatest

PLATE 25.

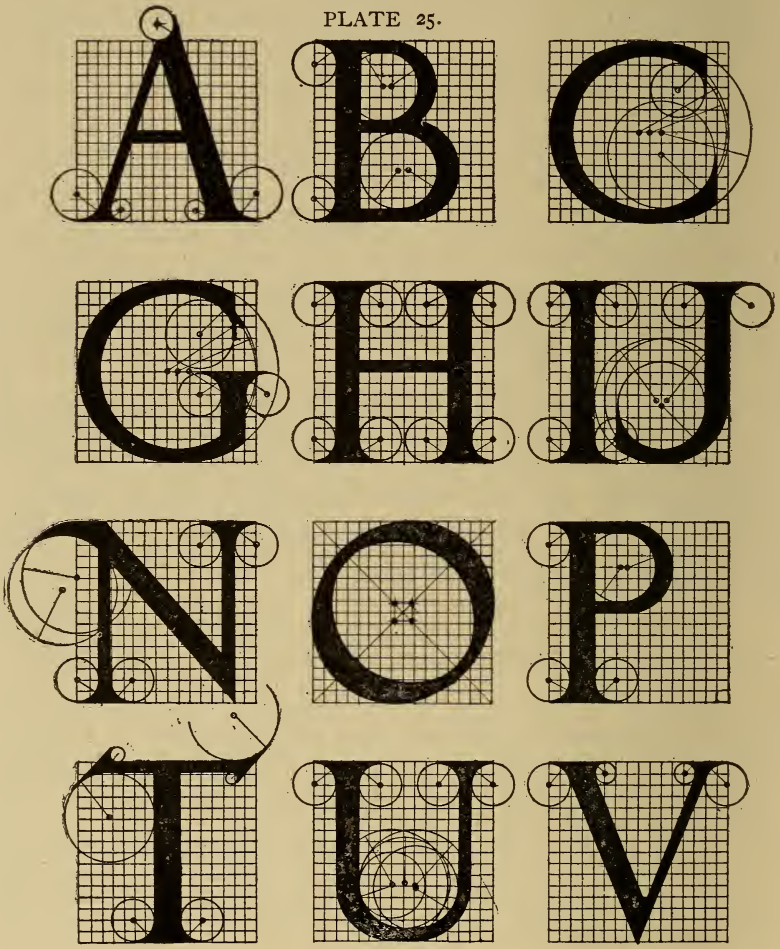


FIG. 241.

PLATE 25.

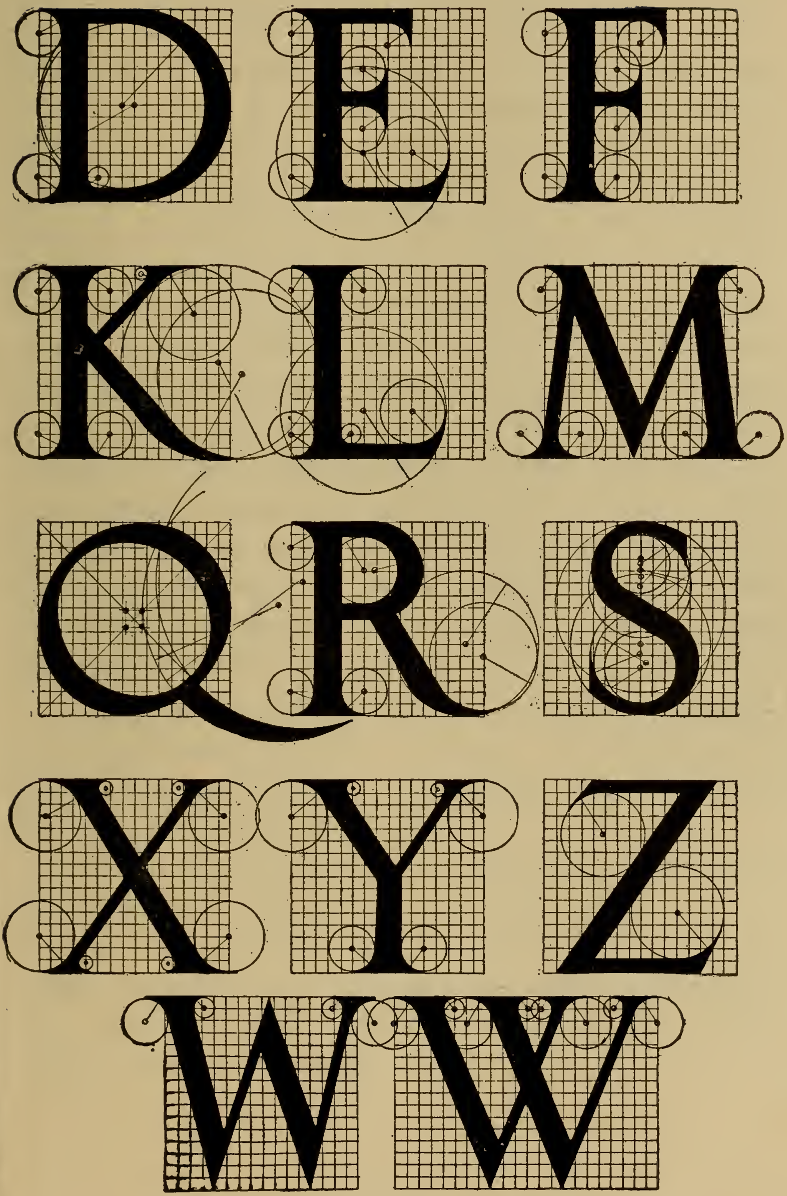

D
E
F
K
L
M
Q
R
S
X
Y
Z
W
W

Fig. 242.

appearance with a maximum of legibility and requires the least amount of labor and time to construct it; while the former is expected to use a style of letter suggested by the character of the drawing to be named and noted.

The alphabet shown in Figs. 241–242, known as the classic Renaissance letters, is selected as a good form of letter for general purposes, where a Roman letter would be suitable for the work in hand. This alphabet was originally designed by Albrecht Dürer and adopted by Frank Chouteau Brown, in his treatise on "Letters and Lettering," Bates & Guild Company, Boston. Mr. Brown's book is recommended to those students who desire to follow up their studies in architectural lettering.

The method used for the instrumental construction of these letters is similar to that used in the Roman letter given on page 67.

For the purpose of learning the form and proportions of these letters the alphabet should be drawn mechanically to a scale as large as convenient; after which practice should be had by forming the letters freehand to smaller sizes, until the student becomes familiar with their construction.

ORDERS OF ARCHITECTURE.

There are, generally speaking, five orders of architecture, the Tuscan, the Doric, the Ionic, the Corinthian, and the Composite, but in reality there are only three, because the Tuscan may be regarded as a simplified Doric, and the Composite as a Corinthian modified by the Romans in an endeavor to surpass the Greeks. (Vignola.)

Tuscan Order.—Fig. 243 shows the pedestal, base, entablature, and capital of the Tuscan order. The dimensions are given in inches, but the drawing may be made by using a scale of modules given in the figure.

A module is an arbitrary term for a unit of measure or proportion partie, or minute, is an arbitrary division of the module. Vignola divides the module for the Tuscan and Doric orders into twelve parts.

The technical names given to the different parts are given in the figure.

Doric Order.—Fig. 244 shows the entablature and capital of the Doric order according to Vignola, The proportions are given in modules and parties. The technical names of some of the details are given in the drawing.

Fig. 245 shows the elevation and plan of the entablature of the Doric Order. Fig. 246 gives the complete Order.

Ionic Order.—In Figs. 247–248 are given the pedestal, base, capital, and entablature with some of their details. The proportions are given in modules. See Prob. 59, page 45, in connection with the drawing of the volute.

PLATE 26.

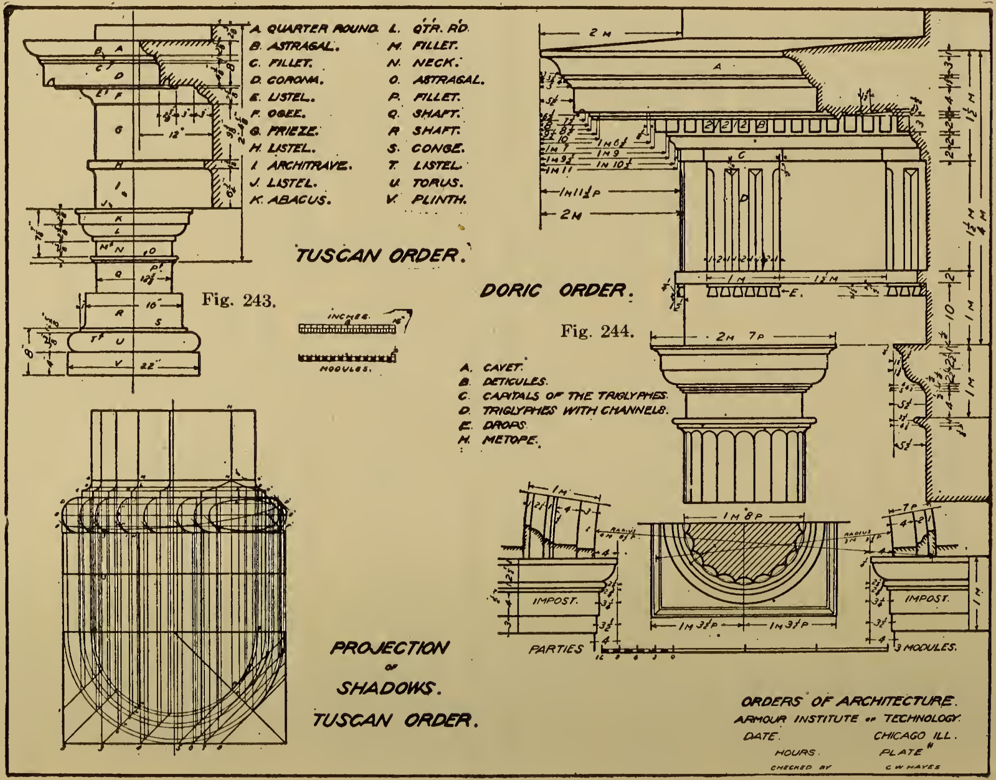
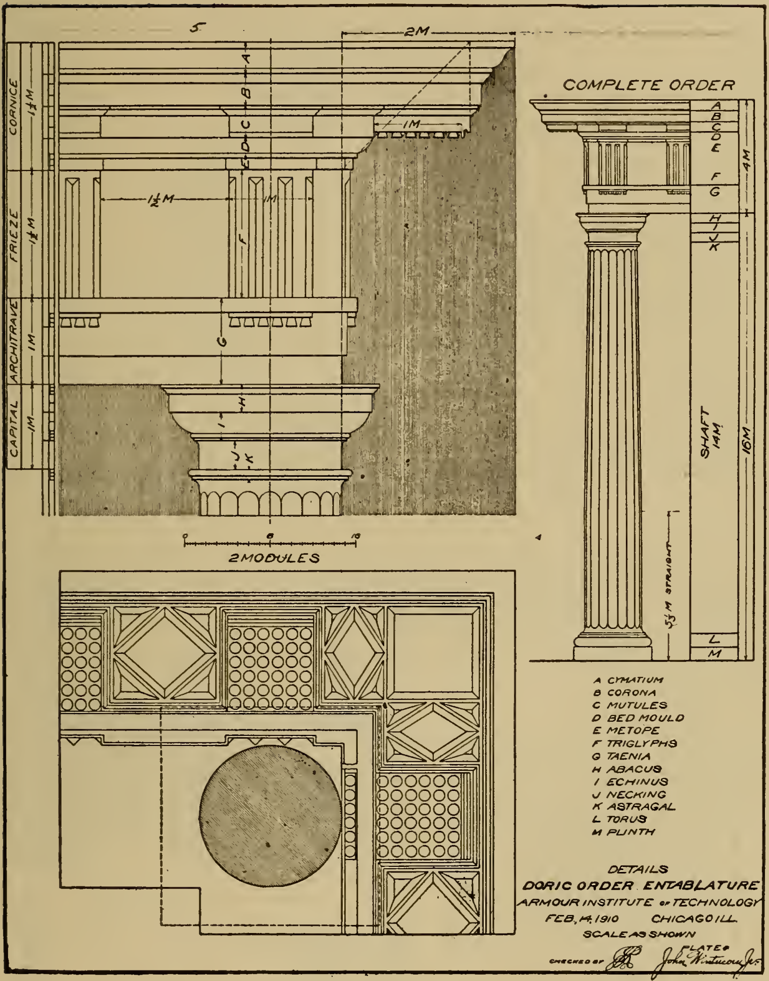


Fig. 243.

Fig. 244.

A. QUARTER ROUND.
B. ASTRAGAL.
C. FILLET.
D. CORONA.
E. LISTEL.
F. OGEE.
G. FRIEZE.
H. LISTEL.
I. ARCHITRAVE.
J. LISTEL.
K. ABACUS.
L. QTR. RD.
M. FILLET.
N. NECK.
O. ASTRAGAL.
P. FILLET.
Q. SHAFT.
R. SHAFT.
S. CONGE.
T. LISTEL.
U. TORUS.
V. PLINTH.
TUSCAN ORDER.
INCHES.
MODULES.
DORIC ORDER.
A. CAVET.
B. DETICULES.
C. CAPITALS OF THE TRIGLYPHES.
D. TRIGLYPHES WITH CHANNELS.
E. DROPS.
H. METOPE.
IMPOST.
IMPOST.
PARTIES
3 MODULES.
PROJECTION OF SHADOWS.
TUSCAN ORDER.
ORDERS OF ARCHITECTURE.
ARMOUR INSTITUTE OF TECHNOLOGY.
DATE.
CHICAGO ILL.
HOURS.
PLATE
CHECKED BY
C W HAYES

PLATE 27.


5
2M
CORNICE
1¼M
FRIEZE
1¼M
ARCHITRAVE
1M
CAPITAL
1M
A
B
C
D
E
F
G
H
I
J
K
1M
1½M
1M
0
8
10
2 MODULES
COMPLETE ORDER
4M
SHAFT 14M
16M
5⅓ M STRAIGHT
L
M
A CYMATIUM
B CORONA
C MUTULES
D BED MOULD
E METOPE
F TRIGLYPHS
G TAENIA
H ABACUS
I ECHINUS
J NECKING
K ASTRAGAL
L TORUS
M PLINTH
DETAILS
DORIC ORDER ENTABLATURE
ARMOUR INSTITUTE OF TECHNOLOGY
FEB. 14. 1910 CHICAGO ILL.
SCALE AS SHOWN
CHECKED BY
PLATE
John Wintucow Jr.

FIGS. 245–246.

PLATE 28.

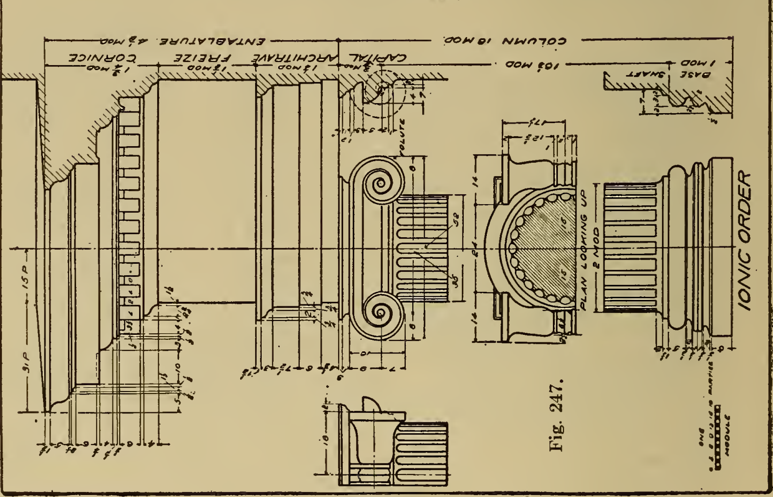

ENTABLATURE 4½ MOD
CORNICE 1¾ MOD
FRIEZE 1½ MOD
ARCHITRAVE 1¼ MOD
CAPITAL ⅔ MOD
COLUMN 18 MOD
16⅔ MOD
BASE 1 MOD
SHAFT
VOLUTE
PLAN LOOKING UP
2 MOD
IONIC ORDER
MODULE
PARTIES

Fig. 247.

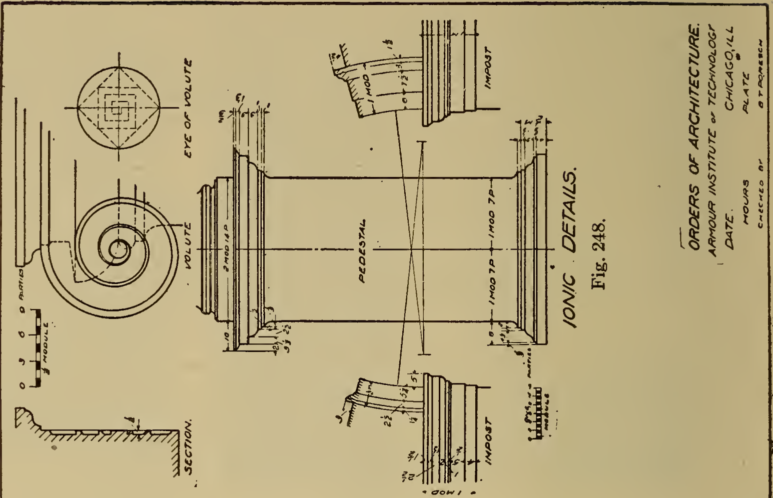

EYE OF VOLUTE
VOLUTE
SECTION
⅓ MODULE
PARTIES
PEDESTAL
3 MOD 16 P
1 MOD 7 P
IMPOST
1 MOD
IONIC DETAILS
MODULE
ORDERS OF ARCHITECTURE.
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.
DATE.
PLATE
HOURS
CHECKED BY

Fig. 248.

CHAPTER VII.

ARCHITECTURAL DESIGN.

In this chapter are given some notes and suggestions on the design and construction of a modern American dwelling house, to be followed with the plans and specifications of a concrete example showing the practical working drawings prepared by Brown Bros., architects, Cedar Rapids, Iowa.

Each student will be expected to modify this design and produce the plans and specifications of a dwelling distinctly different in interior arrangement and exterior design, using the given drawings as suggestive examples only.

Sketches.

When about to prepare drawings of a dwelling for a customer the architect must acquaint himself with all the conditions connected with the problem.

The location of the lot and its size, the amount of money available for the completed house, and the ideas of the customer as to number and size of rooms, interior arrangement and exterior design, etc. When these are learned he will prepare a sketch and submit it for approval, when the sketch for the general arrangement and design has been agreed upon.

Working Drawings.

The working drawings can be made and the specification and contract drawn up ready for signature. When the contract is signed the architect will prepare the full-size detail working drawings, placing as many as possible on one sheet to facilitate the reading of the same by the workmen.

The scale of $\frac{1}{4}''$ equal to 1 foot is generally used in making the plans and elevations, but of course this varies according to conditions.

SPECIFICATIONS

FOR ALL LABOR AND MATERIALS REQUIRED IN THE ERECTION AND COMPLETION OF
A FRAME RESIDENCE
FOR
MR. GEORGE M. VERITY,
TO BE BUILT AT
MIDDLETOWN, OHIO.

ALL WORK AND MATERIALS TO BE IN STRICT ACCORDANCE WITH ACCOMPANYING DRAWINGS AND THE FOLLOWING SPECIFICATIONS, PREPARED FOR THE PURPOSE BY
BROWN BROTHERS,
ARCHITECTS.
808–9 Security Savings Bank Building, Cedar Rapids, Iowa.

General Conditions.

The owner reserves the right to accept or reject any or all bids. The work is to be laid out by the contractor, who will be responsible for its correctness. A competent foreman is to be kept at the building during all working hours to receive and carry out the orders given by the superintendent.

The following specifications and the above mentioned drawings are intended to correspond and be illustrative of each other, and any part of the work that may be mentioned in the specifications and not shown on the drawings, or *vice versa*, is to be executed the same as though it had been particularly mentioned and shown

PLATE A.

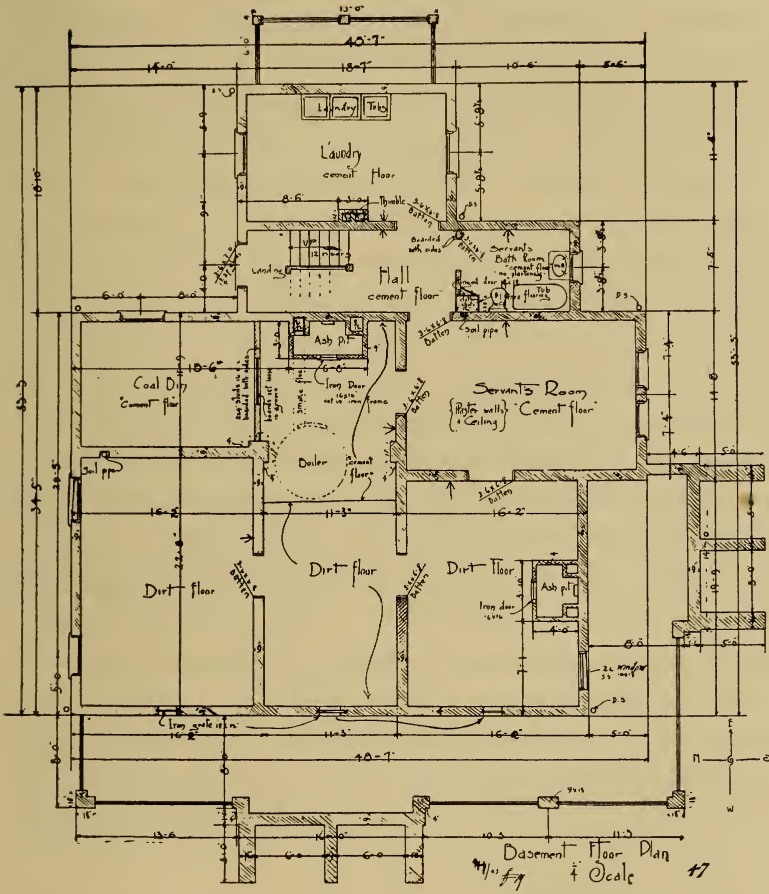

40'-7"
18-7"
16-0"
10-6"
5-6"
Laundry
Tubs
Laundry cement floor
Thimble
Hall cement floor
Landing
UP 12 risers
Servant's Bath Room
Tub
Soil pipe
Ash pit
Iron Door
Smoke flue
Servant's Room
Plaster walls + Ceiling
"Cement floor"
Coal Bin
"Cement floor"
Boiler
"cement floor"
Soil pipe
Dirt floor
Dirt floor
Dirt Floor
Ash pit
Iron door
Iron grate in
16-2"
11-3"
16-2"
5-0"
48-7"
13-6
10-5
11-3
6-0
6-0
Basement Floor Plan
1/4" Scale
N
E
W
S

FIG. 249.

Residence for G. W. Wilson, Champaign, Ill., Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

in both. No deviations are to be made from the drawings or specifications without the written consent of the owner and architect. If any work is, in the opinion of the superintendent, executed in a slight or unsound manner, the same shall on his orders be immediately pulled down and made right at the sole expense of the contractor. None but the most skillful workmen are to be employed on the work and any mechanic or laborer employed thereon who, in the opinion of the superintendent, shall prove careless or incompetent, shall be immediately removed therefrom by the contractor when notified to do so by the superintendent. No part of the work is to be done as "piece work," nor let to a sub-contractor, without the consent of the owner. All materials required for the execution of the work to be furnished by the contractor, unless otherwise specified, must be of the very best quality of their respective kinds, and to be properly applied at times as directed by the superintendent.

All work is to be done in a substantial and workmanlike manner, and if any difference of opinion shall arise as to the quality or quantity of workmanship or materials or upon any other matter connected with the building, the contractor must in all cases be bound by the decision of the architect or superintendent. The superintendent may cause to be removed at any time before the acceptance of the work any materials or workmanship that does not comply strictly with the requirements of the plans or specifications, or in the event that such removal might cause damage or injury to the other portions of the work, or if the contractor neglects or refuses to remove same, then the architect or superintendent may deduct from the amount of the contract price a sum that in his judgment shall be just and reasonable as a set-off to the injury to the building caused by non-compliance with the requirements of the specifications, as well as for the difference of value between the specified and the inferior workmanship or materials, and give his certificate only for the balance that may be due the contractor. The architect shall have full power to have the work pushed forward, and in default of the compliance by the contractor with the terms of a notice to that effect within three days of the service of the same, the architect shall have full power to enter the premises and entirely stop the work, and exclude the contractors therefrom and to furnish all materials necessary, or to use materials then on the premises, or to employ any other workmen to finish such work that may remain unperformed or unfinished, and charge the amount of such unfinished or unperformed work to the original contractor, with all other expenses or costs that may accrue by reason of said change, and to have full power to retain the amount of such costs and expenses out of any moneys that may then be due or coming due from the original contractor.

The contractor shall thoroughly scrape and sweep the floors throughout and remove all rubbish from the premises; also see that all sash, doors, locks, etc., are in proper working order, and shall furnish the proper keys for all locks and leave the entire building ready for occupancy.

STAKING OUT.

Contractor must stake out the building, and he must establish all levels and pay all charges for engineer, if services of an engineer are found to be necessary.

BOND.

The contractor will be required to furnish a surety bond acceptable to the owner, and be ready to sign contract and execute bond within three days after date of the acceptance of his bid, bond to be equal to fifty (50%) per cent of the amount of the contract. A certified check for —— dollars ($——) must accompany each bid as a guarantee that contractor will sign up at his figures within three days after bids are opened, otherwise check is forfeited to owner.

PERMITS.

Contractor must obtain and pay for all building permits and street permits, and comply with local building ordinance in every respect. Proper danger signals must be maintained at night and barriers erected to protect the public from accidents. Should any accident occur by reason of neglect on the part of the contractor, he will be held personally liable for same.

EXCAVATIONS.

Excavate for all walls and piers to a depth as shown on the several drawings and sections. All trenches must be of the depth as shown, and the bottom of all excavations must be perfectly level before any masonry work is commenced in same. All dirt not needed on the premises is to be carried away at the expense of the contractor only after having received an order to do so from the owner. The grades are shown on the drawings and the contractor is to be governed by same in making his calculations. In taking the dirt from the main excavations the loam is to be stacked in one place and the under soil in another, so

PLATE B.

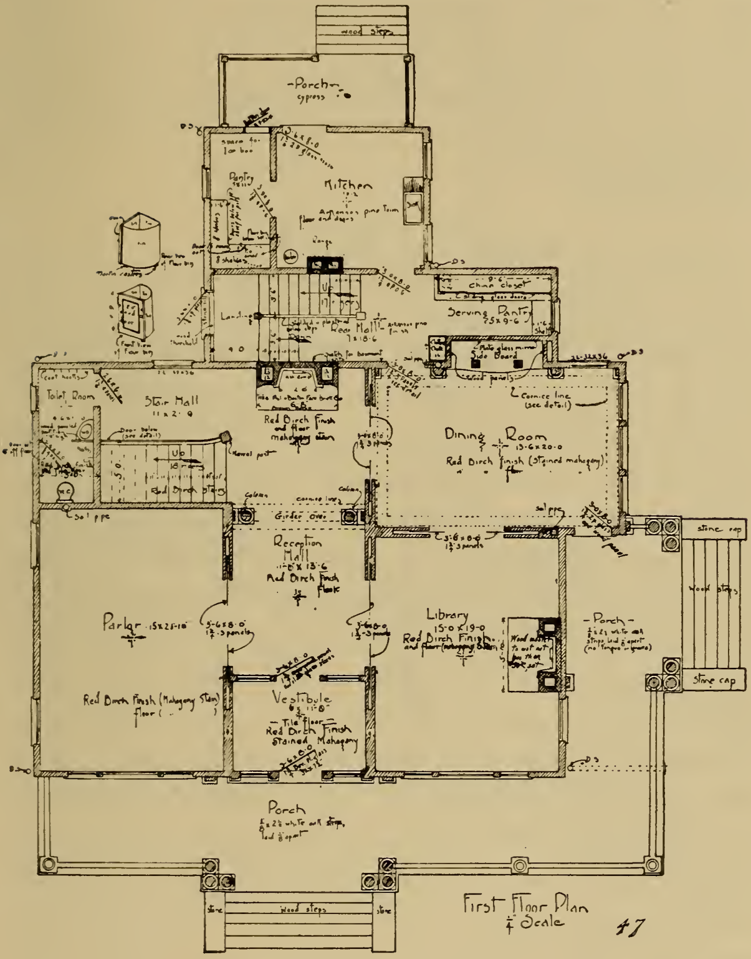

wood steps
-Porch-
cypress
Kitchen
Pantry
Landing
Up
Rear Hall
7x18-6
China closet
Serving Pantry
5x9-6
Side Board
Toilet Room
Stair Hall
Up
Red Birch Finish
Cornice line (see detail)
Dining Room
13-6x20-0
Red Birch finish (stained mahogany)
floor
Girder over
Reception Hall
Red Birch Finish
Floor
Parlor
Red Birch Finish (Mahogany Stain)
floor
Library
15-0x19-0
Red Birch Finish
-Porch-
stone cap
Wood steps
Stone cap
Vestibule
Tile floor
Red Birch Finish
Stained Mahogany
Porch
Wood steps
First Floor Plan
1/4 Scale
47

FIG. 250.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

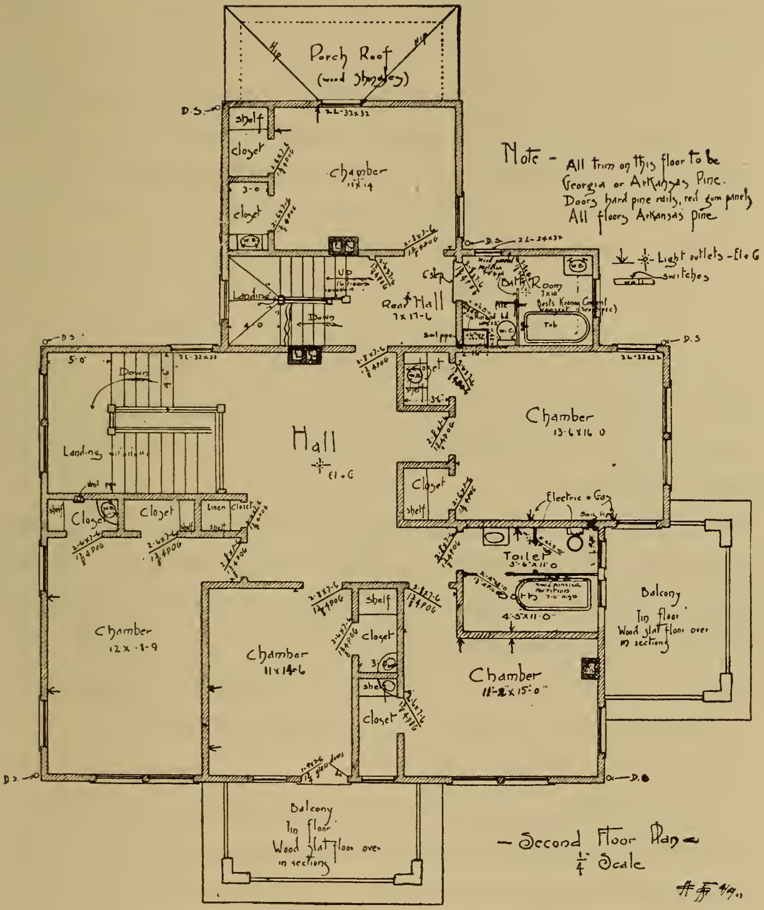
that when grading is done the black loam can be placed on top again. All trenches and cellar bottoms are to be thoroughly drained of all water before any masonry work is commenced. The grading back of dirt that has been thrown out of excavations will be done by another contractor or agreed upon with owner in this contract.

Masonry Work.

All walls, piers, chimneys, etc., in basement and wherever shown on plans and elevations are to be of concrete, or of good hard-burned merchantable brick, laid in lime mortar, as shown by the plans and sections. Submit alternate bid on brick walls. All concrete to be made of good Portland cement (Atlas or its equal, subject to the approval of the architect) and good coarse gravel (or crushed rock in size to pass through a 2″ ring) and clean, sharp sand. Proportions to be as follows: one part of cement, six parts of gravel or crushed rock, and three parts sand. If gravel is used in place of crushed rock, omit the two parts of sand from mixture. All to be thoroughly mixed dry on a board platform and then mixed with water to the proper consistency. All concrete must be kept thoroughly wet for at least two days after having been placed in the forms. Forms to be made of rough plank sides of inch lumber and to be firmly braced and kept in place until the concrete has properly set. Build in all pipes through concrete walls as work progresses. All exposed face brick to be Twin City Brick Co.'s (or its equal) oriental brick, Minneapolis, Minn. (medium and dark shades, one-half of each), and to be laid up with $\frac{1}{2}$″ mortar joints and raked out $\frac{3}{4}$″ deep.

Build chimneys and fireplaces as shown on drawings, sections and details of materials as marked on drawings and line all smoke

PLATE C.


Porch Roof
(wood Shingles)
D.S.
shelf
closet
chamber
11x14
3-0
closet
Landing
Up
Down
Rear Hall
7x17-6
Bath Room
7x10
Tub
W.C.
Note - All trim on this floor to be Georgia or Arkansas Pine. Doors hard pine rails, red gum panels All floors Arkansas pine
Light outlets - El & G
switches
wall
D.S
Hall
El. & G
Down
Landing
5-0
Closet
shelf
Closet
Linen Closet
Closet
shelf
Chamber
13-6x16-0
Electric & Gas
Soil Pipe
Toilet
5-6"x11'0
Bath
4-5"x11-0"
Balcony
Tin floor
Wood slat floor over in sections
Chamber
12x-8-9
Chamber
11x14-6
shelf
closet
shelf
closet
Chamber
11-2"x15-0"
Balcony
Tin floor
Wood slat floor over in sections
D.S.
— Second Floor Plan —
1/4" Scale
#F 49.

47

FIG. 251.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

flues with fire-clay flue linings. All chimney work to be laid up with lime mortar with a little cement added. Turn discharging arches over each fireplace and support heads of all square openings of fireplaces with H. W. Covert's cast-iron throat and damper, with four (4) inch bearing on walls at front, back and ends. Place thimbles in all chimneys where directed by superintendent. For design of mantel, see details. Line all fire openings with fire-brick laid in fire-clay mortar.

Cistern.—Provide and put in a 100 bbl. cistern where directed by the owner. This cistern is to be built of good hard-burned merchantable brick 4″ thick, laid in cement mortar for bottom, sides and arched top, and to have a ½″ smooth coat of cement mortar (one part cement to one of sand) for the finished surface of walls and bottom.

Cistern is to be circular in plan and to be about 8′ in diameter by the proper height to contain 100 bbls. of water. Provide a filter wall on a slight curve in center of cistern, and to extend to within 18″ of the top. This filter wall is to be laid up of one course of brick without any mortar. Provide a cast-iron rim 28″ in diameter by 6″ high to finish off the top, and also provide a cast-iron cover with 3″ ring.

Top of cistern cover to be about 12″ below finished grade of house when completed. Make all proper connections from water pipes leading from down spouts to the cistern, and have all pipes from down spouts enter cistern wall on same side of filter wall. Provide opening in cistern wall to receive the pipe from water lift and connection to hot water heater. Provide 6″ vitrified salt-glazed sewer pipes with cemented joints to connect up with all down spouts and cisterns and lay same at least 2′ 6″ below finished grade of house. Provide a fall of at least ¼″ to the foot for all pipes. These sewer pipes are to extend 8″ above finished grade line at each down spout, and to be thoroughly cemented around all spouts. Provide proper overflow pipe to cistern and cutoffs for down spouts at ground.

Water-Proofing of Walls.—Cover the exterior surface of all outside basement walls from bottom of footings up to finished grade line and over top of wall at this level with one coat of hot asphaltum or dehydratine.

Cement Work.

Over entire basement floor and wherever marked "cement floor" on plans, is to have a cement floor consisting of 3″ bed of concrete, composed of one part of Atlas Portland cement to six parts of crushed rock and three parts of clean, sharp bank sand. Top coat to be ½″ thick, composed of one part of same cement as above specified to two parts of clean, sharp bank sand, troweled to a perfectly even and polished surface and lined off in squares approximately 48×48″.

Lathing.

All stud walls, partitions and ceilings of first story are to be lathed with No. 1 pine, spruce or yellow poplar lath, free from red knots or bark, and well seasoned; break joints at least every 18″. Place lath ⅜″ on the ceilings and but very little closer on the stud walls. No lathing through the angles allowed; all walls to be made solid by the carpenter before lathing begins.

Half green lath are preferred, but if bone dry, wet the lath well before plastering.

PLATE D.

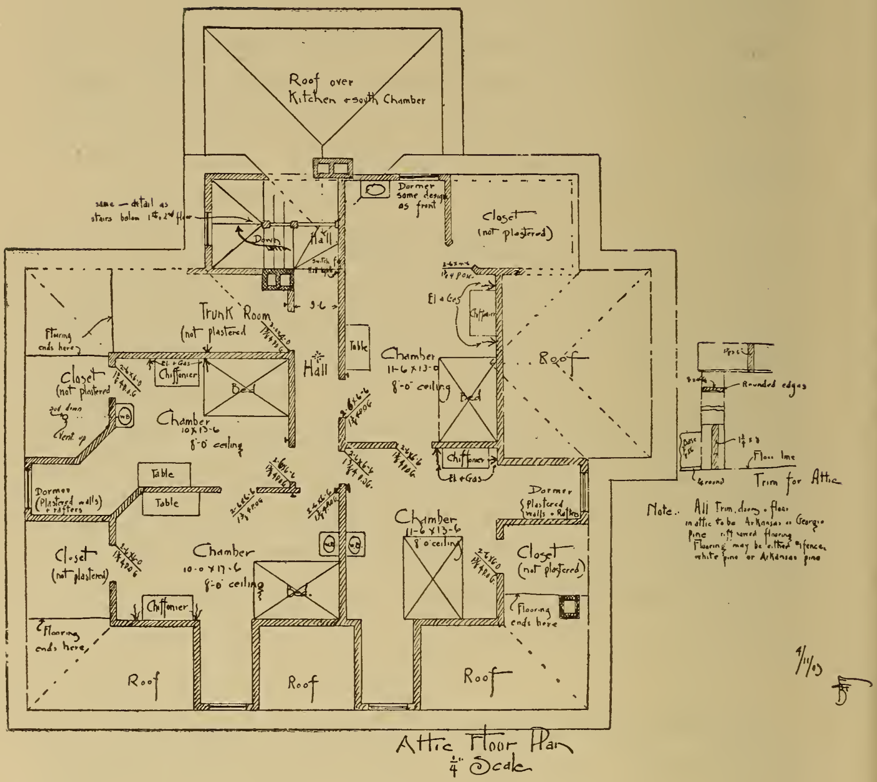

Roof over
Kitchen + south Chamber
same — detail as
stairs below 1st, 2nd floor
Down
Hall
Switch for hall light
9-6
Dormer
same design
as front
Closet
(not plastered)
1-6 x 4-4
1 3/4 4 pan.
El + Gas
Chiffonier
Flooring
ends here
Trunk Room
(not plastered
2-6 x 4-0
1 3/4 4 p. o. G
Closet
(not plastered
2-6 x 6-0
1 3/4 4 p. o. G
El. + Gas
Chiffonier
Bed
Hall
Table
Chamber
11-6 x 13-0
8'-0" ceiling
Bed
Roof
2-6 x 6-6
1 3/4 4 p. o. G
2-6 x 6-4
1 3/4 4 p. o. G.
2-6 x 6-6
1 3/4 4 p. o. G
Chiffonier
El + Gas
soil down
W.B.
Vent up
Chamber
10 x 13-6
8'-0" ceiling
Table
Table
Dormer
(Plastered walls)
+ rafters
2-6 x 6-6
1 3/4 4 p. o. G
2-6 x 6-6
1 3/4 4 p. o. G
2-6 x 6-6
1 3/4 4 p. o. G
Dormer
{Plastered
walls + Rafters
Chamber
11-6 x 13-6
8' 0" ceiling
W.B.
W.B.
Closet
(not plastered)
2-6 x 6-0
1 3/4 4 p. o. G
Chamber
10-0 x 17-6
8'-0" ceiling
Bed
Closet
(not plastered)
2-6 x 6-0
1 3/4 4 p. o. G.
Chiffonier
Flooring
ends here
Flooring
ends here
Roof
Roof
Roof
Rounded edges
1 3/4 x 8
Base
Floor line
Ground
Trim for Attic
Note.. All Trim, doors + floors
in attic to be Arkansas or Georgia
pine rift sawed flooring
Flooring may be either of fence
white pine or Arkansas pine
4/11/03
Attic Floor Plan
1/4" Scale

FIG. 252.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

PLASTERING.

Plaster all interior wood lath with "Adamant" patent wall plaster (or its equal "Universal,") to be put on according to the printed instructions of the manufacturers. Plaster to come to the building ready mixed with nothing but the water to be added. This is to be two-coat "drawn work," and all walls and ceilings are to be given a hard, smooth plaster-of-paris finish in the universal white finish (all for papering).

Use $\frac{3}{4}''$ grounds around all openings for interior work for baseboards, wood strips, etc., in the building. All plaster must come up flush with grounds and be roded perfectly straight, true and plumb.

All patching of plastering to be done by the plasterer after all woodwork is complete. Plasterer to clean out all his rubbish and scaffolding from the buliding when his work is completed.

PLASTER WAINSCOATING.

The walls of kitchen, bath and toilets are to have a good patent plaster wainscoting—Keene's Best Cement or its equal—4′ 6″ high; to be two-coat work. First coat to be a scratch coat; second coat to be troweled to a perfectly smooth, even and polished surface.

Timbers.—All timbers, girders, trimmers, joists, truss beams, partitions, studs, rafters, etc., must be prepared, framed and constructed according to the drawings and sections. All floor joists properly sized to widths and jointed, crowning on top edge.

All "piece stuff" to be clear Georgia, Arkansas or Northern pine.

Joists and built-up girders to be of a size as shown on plans. All joists placed sixteen (16) inches on center.

All built-up girders to be well spiked together.

Bridging.—Cross bridging to be made of sound stuff 2×2″, well fitted, put in as soon as joists are leveled, and spiked with two 10d. nails at each end. Joists from 5 to 8′ bearing one row 12 to 18′, two rows of bridging.

Headers and Trimmers.—To be double thick, well framed and spiked together, leaving all openings of sufficient size for finish of stairs, chimneys, etc., and in no case closer than 5″ to the inside of any smoke flue. All openings in brick or concrete to have wooden lintels or brick arches, not less than 4″ thick, by the required width to cover the thickness of wall. Build in all "wood brick" in brick walls where necessary for nailing.

Partition and Wall Studs.—All studs to be 2×4″ set 16″ on center and doubled and trussed at all openings where required, in substantial manner. Partitions to be sized and jointed, set plumb and straight. All angles of rooms made double and solid. All bearing partitions, and partitions over 6′ in length to be bridged horizontally once in height. All studding to have 2×4″ bearing plates top and bottom.

Closing up Doors and Windows.—When building is ready for plastering, all sash and glass is to be in place, and contractor is to have temporary doors and locks for all outside doors.

Sheathing.—Enclose the entire house, sides and gables with D. & M. fence flooring, $\frac{7}{8}$×6″ yellow pine. Roof sheathing to be $\frac{7}{8}$×6″ S. O. S. No. 2 boards, yellow pine, laid open 2″, properly nailed to every studding and rafter with two nails to the board. Tight sheathing to extend from bottom of studs clear up sides of house and into all gables. Open sheathing on roof only. Fill in between outside studding of bathroom with saw-

PLATE E.

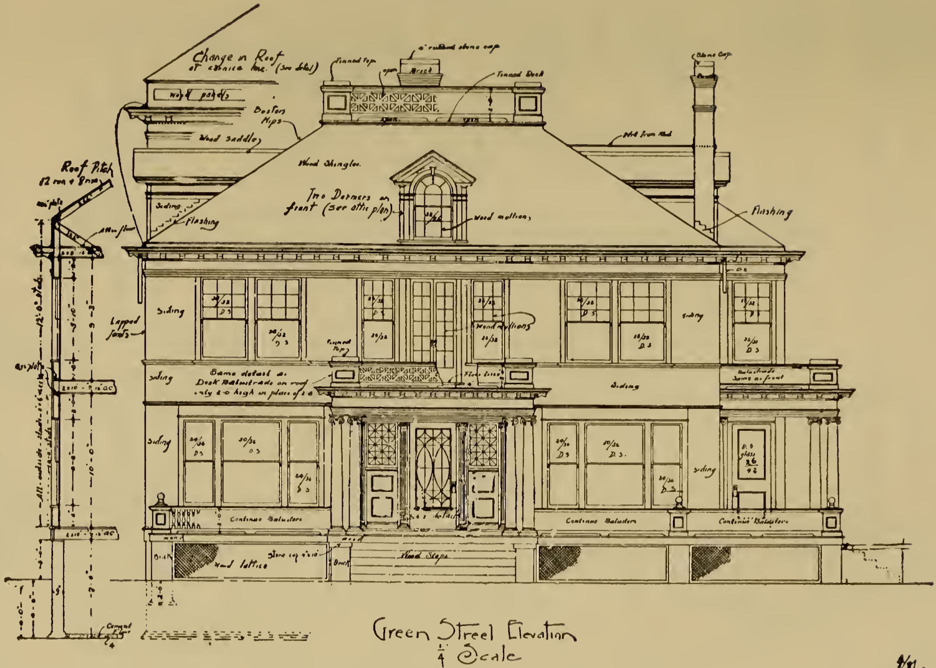

Change in Roof at cornice line (see detail)
wood panels
Boston Hips
Wood saddle
Roof Pitch
Tinned top
open
Brick
Tinned Deck
Wood Shingles
Two Dormers on front (see attic plan)
Wood mullions
Stone Cap
Flashing
Siding
Lapped joints
Same detail as Deck Balustrade on roof only 2-0 high in place of 2-6
Tinned Top
Balustrade Same as front
Continuous Balusters
Wood lattice
Stone cap
Brick
Wood Steps
Green Street Elevation
1/4 Scale

FIG. 253.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

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dust or shavings and pack firm. Cover all sheathing on walls and gables with heavy tarred felt paper well tacked on and fill in between studs of oustide walls with same felt as above specified, so as to leave a double dead air space between sheathing and plastering.

Roof.—The carpenter shall frame and construct, according to the drawings, sections and specifications, in the most thorough manner, all roof rafters, hips, ridges and valleys.

Shingles.—Where shown on drawings on roof and sides to be first clear red cedar shingles, 5 to 2″ and laid 4½″ to the weather, with two 3d. cut iron nails to each shingle. Make perfectly water-tight around all chimneys, skylights, scuttles, etc., gutters, fire-walls or wherever the roof of one part joins the perpendicular walls of another, with flashings. (See tin and galvanized iron specifications.)

All proper bond timbers, cradles for arches, etc., and wooden brick of every description necessary for the proper execution of the work to be furnished by the carpenter; also all lumber necessary for lookouts, decks and furring for the tinners, galvanized iron work, etc.; also build all necessary scaffolding to do the carpenter work properly.

Cornice.—All exterior wood finish to be construted in strict accordance with details and to be of thoroughly seasoned clear cypress. Provide bed mould and beaded ceiling for soffit of all cornices.

Porches.—Build all porches as shown on the plans, elevations and details. Use rough posts, timbers, barge boards, brackets, casings, etc., for all exterior woodwork except sash, doors and frames. Furnish and put in place a 2½″ crown mould all around edge of ceiling to finish same against wall. Porch ceilings to

PLATE F.

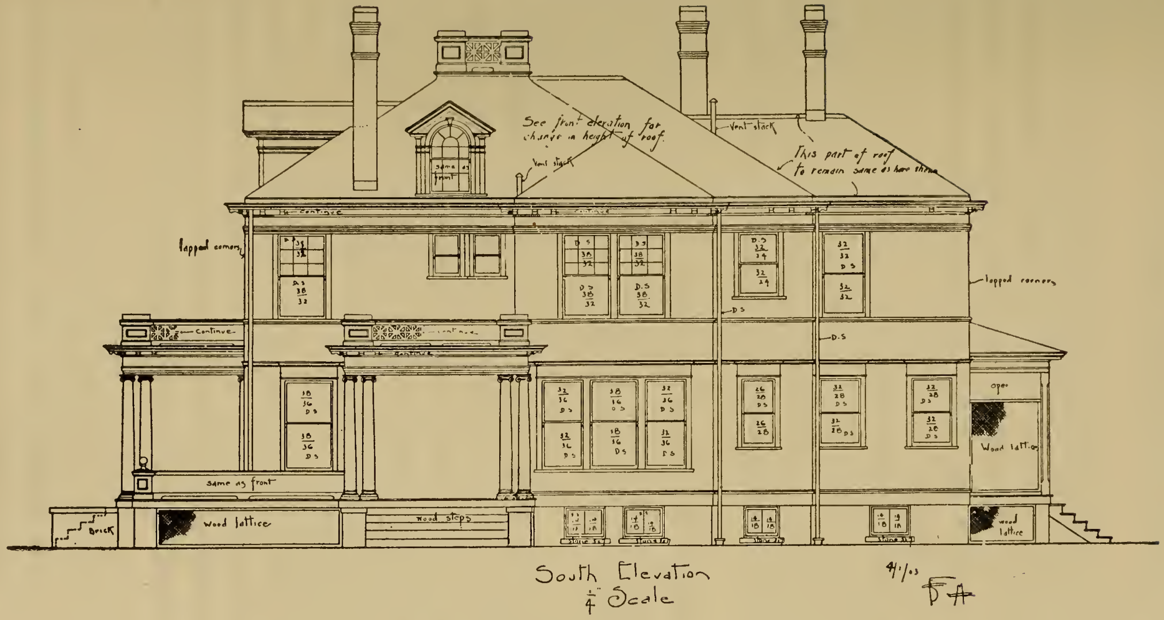
See front elevation for change in height of roof.
Vent stack
Vent stack
This part of roof to remain same as here shown
lapped corners
lapped corners
Continue
Continue
D.S
D.S
same as front
same as front
open
Wood lattice
Wood lattice
wood lattice
Wood steps
Brick
Stone sill
South Elevation
¼" Scale
4/1/03

FIG. 254.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

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have "V" edge and center ceiling to be $\frac{7}{8}\times6''$ clear Washington fir or cypress.

Windows.—All windows for this building must be of the forms, style and dimensions as marked on plans, elevations, sections and details, or as hereinafter described. All pulley stiles to be $\frac{7}{8}''$ thick, of clear yellow pine and provided with best noiseless cast-iron ball-bearing axle pulleys (wheels in one solid piece). Sash hung to solid braided Silver Lake "A" or "Sampson Spot" sash cord and cast-iron weights. Use lead weights where necessary. Sash to be of clear seasoned white pine $1\frac{3}{8}''$ thick and to have extension ends to side rail of upper sash for all double-hung windows.

All casement sash hinged at side to swing out. Screen sash on casement windows, hinged at side to swing in. All windows to be equipped with Chamberlain's metal weather strips all around.

Frames.—All frames to be made of $\frac{7}{8}''$ pulley stiles, $\frac{7}{8}''$ head of clear yellow pine, and $1\frac{3}{4}''$ sills of clear Washington fir or cypress. Door frames for outside doors $1\frac{3}{8}''$ thick and rabbetted; same material as above. Inside door frames $\frac{7}{8}''$ thick of same wood as finish of rooms, and use wood stops $\frac{1}{2}\times1\frac{1}{2}''$ with moulded edge. (See details.)

Plank Frames.—Basement frames to be of clear cypress or Washington fir $1\frac{3}{4}''$ thick. All frames must come to the building primed with white lead and linseed oil, one coat. Basement window frames to have clear Washington fir or cypress sills $1\frac{3}{4}''$ thick.

Floors.—The first story joists will first be covered with $\frac{7}{8}\times6''$ D. & M. fence flooring, yellow pine. Finished floors of living-room and dining-room to be quarter-sawed clear yellow pine.

$\frac{7}{8}\times 2\frac{1}{2}''$ face, T. & G. sides and ends, and no boards to be less than 4″ long.

All finished flooring to be first clear $\frac{7}{8}\times 2\frac{1}{4}''$ face, T. & G. sides and ends, well secret-nailed to every joint. All other floors except as above specified to be clear quartered Arkansas or straight-grained Oregon pine, $\frac{7}{8}\times 4\frac{1}{2}''$, T. & G. sides and ends.

Finished floors must be planed and scraped before staining or varnishing. All floors must be well protected before varnishing, until house is entirely completed. Then staining and varnishing to be done the last thing. No finished floors to be laid until all other workmen except painters are through.

All under floors to be laid diagonally and end joints cut on a line parallel with joists, and to lap half the thickness of joists and well nailed with two nails to each end of the board and with two nailings on each intermediate joist.

Porch floors, unless marked "cement" on plan, to be $\frac{7}{8}\times 4''$ clear-matched Washington fir or cypress, laid in white lead, and well drawn up and nailed to every joist.

Grounds.—Put up grounds for the finish of all windows, doors, bases, casings, wainscoting, etc., before plastering. Those on wooden partitions to be $\frac{3}{4}\times 1\frac{1}{2}''$; on brick walls, $\frac{5}{8}\times 1\frac{1}{2}''$.

Closets.—All closets finished with two shelves to each unless otherwise shown on details and plain wood strips extending around closets $\frac{7}{8}\times 4''$ wide on which to fasten clothes hooks. All pantry and kitchen cupboards to have plain doors (no panels), $\frac{3}{4}''$ thick, and to have shelves 12″ apart, set on adjustable wood strips with cast-iron pin adjusters. Below counter shelves provide drawers, bins and doors as marked on plans. All drawers to have center oak guide strips underneath. Glass doors to

PLATE G.

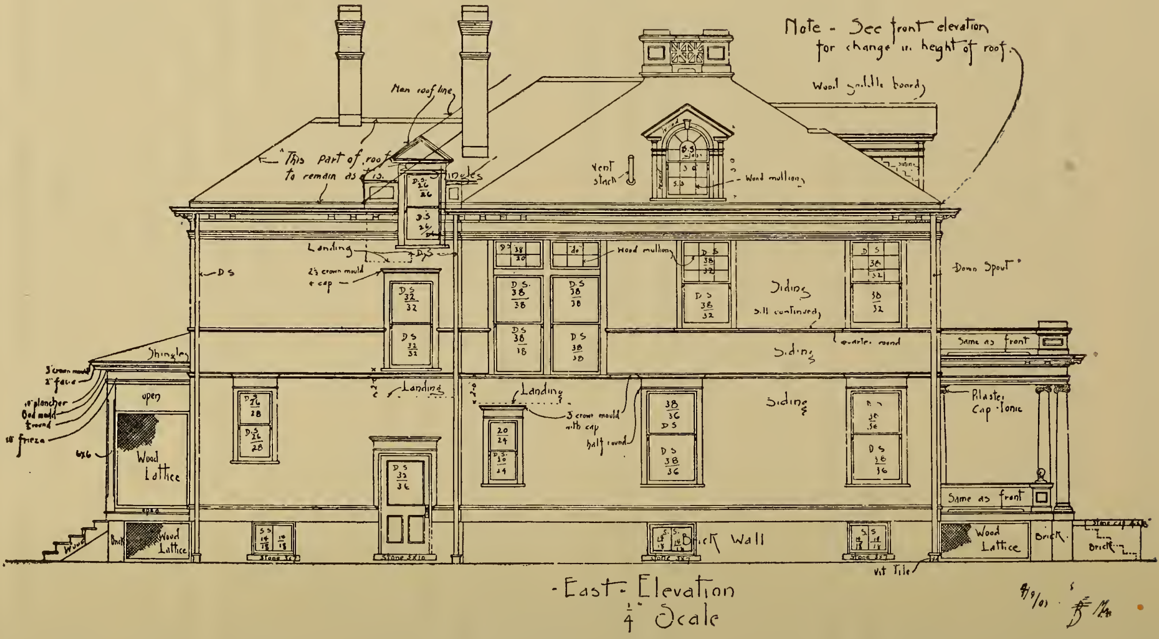
Note - See front elevation for change in height of roof.
Wood saddle board
Man roof line
"This part of roof to remain as it is.
Shingles
Vent stack
Wood mullions
D.S.
Landing
D.S
2½ crown mould & cap
Wood mullion
Siding
Sill continued
Quarter round
Down Spout
Shingles
3" crown mould
2" facia
15" plancher
Bed mould
½ round
15" frieze
6x6
open
Wood Lattice
Landing
Landing
3" crown mould with cap
half round
Siding
Pilaster Cap Ionic
Same as front
Same as front
Wood
Brick
Wood Lattice
Stone 5x7
Stone 5x10
Brick Wall
Stone 5x7
Stone 5x7
Wood Lattice
Brick
Brick
Stone cap
Vit Tile
- East - Elevation
¼" Scale
4/9/01

FIG. 255.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

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cupboards where shown to be AA double strength clear glass, put in with wood stops nailed in place.

Wainscoting.—No wood wainscoting in the building.

Doors.—All doors must be made of material same as standing finish of the rooms in which they occur, thoroughly seasoned, and of the sizes marked on plans, fitted in their respective places, hung and trimmed complete. All doors, except as otherwise shown, to be fine cross panel O. G. stock doors. No veneered doors in house.

All cupboard doors to be plain, $\frac{3}{4}''$ thick (no panels). All glass doors to be glazed as shown on drawings, with D. S. clear glass unless otherwise marked. Picture mould in all rooms and halls except kitchen, bathroom and pantry of same wood as other wood finish in the rooms in which it occurs.

Finish.—All standing finish of living-room and dining-room to be clear, quarter-sawed chestnut. All other standing wood-work to be clear straight-grained Arkansas or Georgia pine.

All interior finish to be thoroughly kiln dried. (See painting specifications for paint and varnishes.) All door and window casings, base, etc., in the several rooms to be the style, form and dimensions as per detailed drawings. All casings, bases, etc., to lap well over the ground and fit perfectly to the plastering, and no finish is to be put up before plastering is thoroughly dry. Furnish and put up hardwood corner strips, where required, at all exposed plaster angles, of $\frac{3}{8} \times 2''$ to extend $5'\ 6''$ above baseboard, and to have plain square top edges, and to be scribed on to baseboard at bottom; corners to be slight rounded. Put up rubber-tipped wood base knobs where necessary for doors to swing against, of same wood as finish of rooms. The whole to be done in the most substantial and workmanlike manner with thoroughly seasoned wood.

All finish to be first clear, except where otherwise specified.

All interior finish must come to the building thoroughly sanded and ready for the varnish or paint.

Bathroom Toilet Cabinet.—Build toilet cabinet in bathroom where shown; to be the Hess Warming and Ventilating Co.'s Sanitary Steel bathroom locker complete (No. 906 Tacoma Bldg., Chicago, Ill.), cased up as directed by architect; to have adjustable and movable enameled steel shelves with rounded edges, and a plate mirror door. Case to be sunk into wall as deeply as possible. Height of case from floor to be as directed by owner.

All interior finish must be absolutely clear and free from knots and black spots except where painted, which can have spots or dark streaks, but no loose knots or soft places.

Beam Ceilings.—All beam ceilings to be as shown on plans and details.

Mantels.—See details for mantel shelves, bookcases, etc., all to be same finish as other finish in rooms in which they occur. Hearths and face to be Grueby Tile, 6×6″, to be selected by owner or built of face brick, as described in masonry work above grade.

Hardware.—Contractor is to furnish and put in place all nails, strap hinges, pulleys, cord and weights for double-hung windows. All finishing hardware will be furnished by owner and put on by contractor.

Glass.—The breakage of glass will be evenly divided between the carpenter, painter, plumber, heating man and plasterer if party who broke the glass cannot be found. All glass, where

PLATE II.

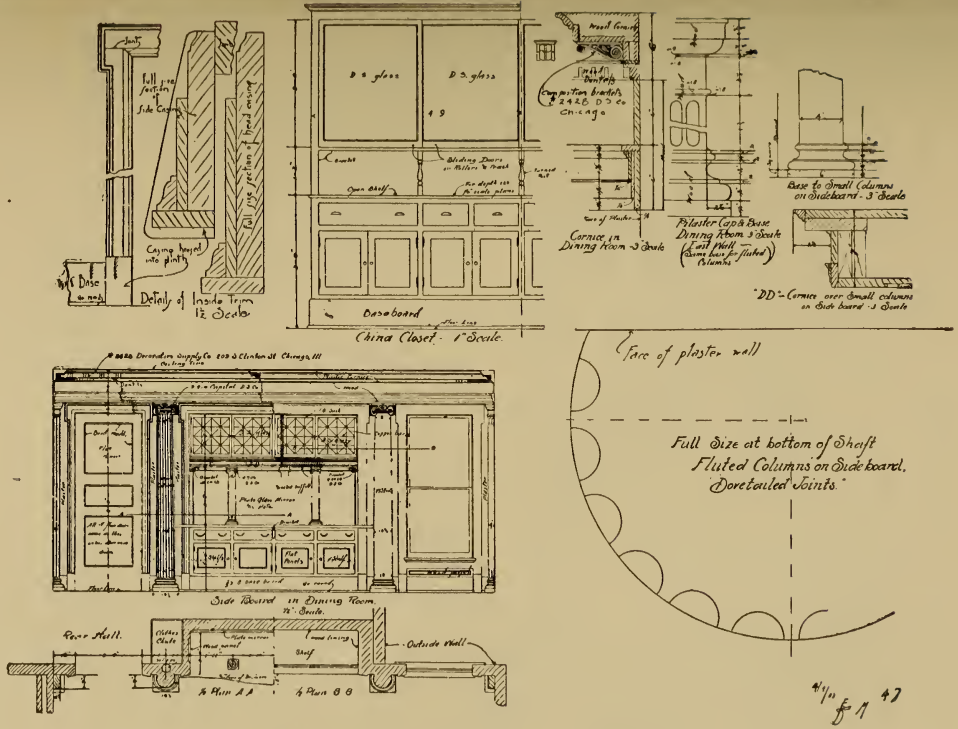

Full size section of Side Casing
Full size section of head casing
Casing housed into plinth
Base
Details of Inside Trim 1½ Scale
D S glass
D S glass
Sliding Doors on Rollers & track
Open Shelf
Baseboard
China Closet - 1" Scale
Wood Cornice
Dentils
Composition brackets 2428 D S Co Chicago
Cornice in Dining Room 3" Scale
Pilaster Cap & Base Dining Room 3" Scale (East Wall — Same base for fluted Columns)
Base to Small Columns on Sideboard - 3" Scale
"DD" - Cornice over Small columns on Side board - 3" Scale
Face of plaster wall
Full Size at bottom of Shaft Fluted Columns on Side board. "Dovetailed Joints."
Decorators Supply Co 209 S Clinton St Chicago Ill
Plate Glass Mirror
Flat Panels
Side Board in Dining Room. ½" Scale.
Rear Hall.
Clothes Chute
Shelf
Outside Wall
½ Plan A A
½ Plan B B
4/1/11 47

Fig. 256.
Residence for G. W. Wilson, Champaign, Ill., Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

not otherwise specified, to be AA double-strength glass, well secured in place.

All glass where marked "Plate" on plans or elevations to be best American Plate $\frac{3}{16}''$ thick and absolutely clear. All mirrors where shown or described to be $\frac{3}{16}''$ plate mirrors, perfectly clear, and of a size shown or specified. Use metal track and small wheels in lower rail of sliding doors in pantry and kitchen. All glass with copper or lead bar muntins to be AA double strength.

Screens.—(Contractor may submit bid screens of his own make, but use same wire and hardware trimming as hereinafter specified.)

Place Willer Mfg. Co.'s (Milwaukee, Wis.) or their equal, patent screens on all double hinge windows and all outside doors. All screen cloth to be best copper bronzed wire, 16 mesh, and drawn perfectly tight.

Casement windows to have screens to cover entire window opening and to be hinged at side to swing in room (see details). All double-hinge windows to have screens on outside to cover half of window and to slide up and down on metal springs and wood strips. Inside screen sash to be constructed of same wood as finish of rooms in which they occur. All outside screen sash for windows to be made of same wood as other exterior finish. Front screen door, No. 151, stiles and rails to be made of quarter-sawed clear white oak or chestnut, and to be braced with brass rod and turnbuckle, also to have spring hinge and rubber-ball bumper. Rear screen door stiles and rails of same wood as other exterior finish, and to have rubber-ball bumper and brace as above. All basement windows to have screens to cover entire window, style No. 3, and to be secured in place by metal thumb turns.

All hardware for screens to be finished by contractor. Use two 3×3″ butts for casement sash; three 4×4″ butts for all

PLATE I.

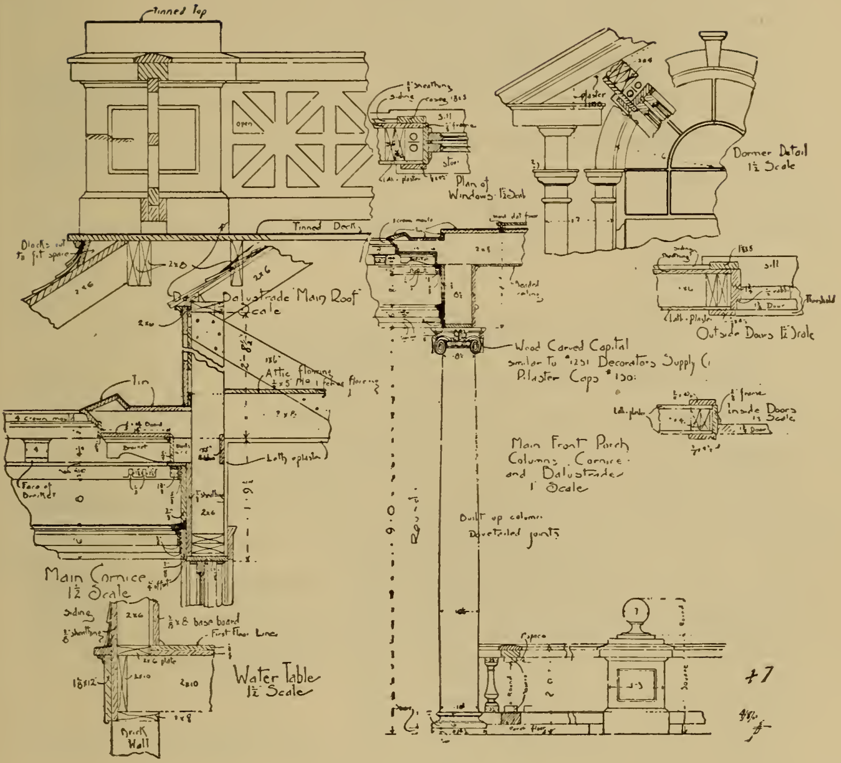

Tinned Top
open
Plan of Windows 1½ Scale
sheathing
siding
casing
sill
frame
stool
lath & plaster
Dormer Detail 1½ Scale
Tinned Deck
crown mould
Beaded ceiling
Blocks cut to fit space
2x8
2x6
Balustrade Main Roof 1½ Scale
Attic flooring
Tin
crown mould
Face of Bracket
Lath & plaster
Main Cornice 1½ Scale
siding
sheathing
2x6
⅞x8 base board
First Flr. Line
2x6 plate
2x10
Water Table 1½ Scale
Brick Wall
Wood Carved Capital similar to #1251 Decorators Supply Co Plaster Caps #130
Outside Doors 1½ Scale
sill
Threshold
Inside Doors 1½ Scale
Main Front Porch Columns, Cornice and Balustrade 1" Scale
Built up column Dovetailed joints
Coping
Porch Floor

FIG. 257.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

screen doors; cup catches for all casement screens. All hardware for screens on outside to be brass. All hardware for screen on inside of building to be steel, plated to match hardware in room. Get style of finishes of hardware from the architects.

The contractor must clear out all lumber, shavings, etc., and all other loose rubbish from all rooms in the several stories, sweep all floors clean, and remove all rubbish from the premises on completion of his contract. All damage to adjoining property caused by this contractor to be repaired and left clean and whole on completion.

TIN AND GALVANIZED IRON AND LEAD WORK.

Down Spouts and Conductor Heads.—All down spouts must be well secured to walls, with ornamental galvanized iron fasteners, and must extend to ground. Gutters to be made of No. 26 galvanized iron and properly graded to down spouts. Provide gutters wherever shown to catch water from the roof, and provide No. 26 galvanized-iron corrugated down spouts, 3×4″, where shown on the drawings, or where necessary to carry the water off the roof to ground. Gutters to run up at least 8″ under shingles.

All valleys to be lined with 20″ N. & G. Taylor's Target and Arrow tin.

Flashings.—Flash around all chimneys, and from roof up into brickwork, and counterflash same with tin as above specified. Provide substantial galvanized-iron fasteners for down spouts where shown. (See details.)

Iron Work.—Provide the Holland Furnace Co.'s (Holland, Mich.) coal window chute for one coal window in basement. Also provide all other cast- or wrought-iron work such as ash-pit

PLATE J.

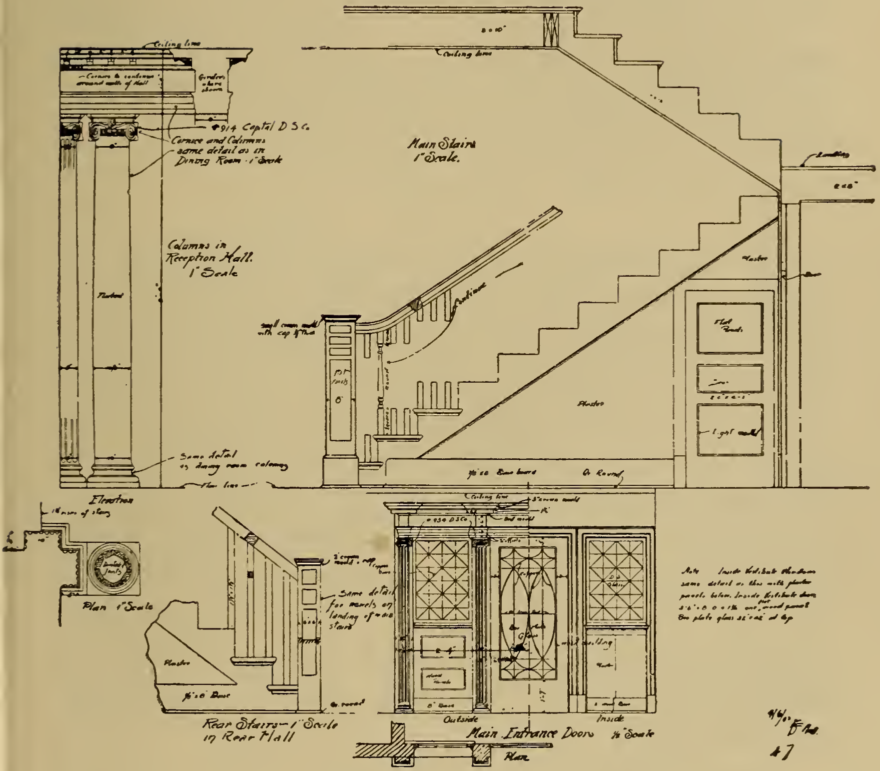

Ceiling line
Cornice & continue around walls of Hall
Girders above
Capital D. S. C.
Cornice and Columns same detail as in Dining Room · 1" Scale
Main Stairs 1" Scale.
Ceiling line
Landing
Columns in Reception Hall. 1" Scale
Plaster
Plaster
Same detail as dining room columns
Floor line
Elevation
Plan 1" Scale
Rear Stairs — 1" Scale in Rear Hall
Plaster
Same detail for newels on landing of rear stairs
Ceiling line
Outside
Inside
Main Entrance Doors ½" Scale
Plan
47

FIG. 258.

Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

doors, frames, etc., and iron throat and damper for fireplace. (Covert's Patent Iron Throat and Damper.)

Guarantee.—The whole of the galvanized iron and tin work must be guaranteed for a term of five years. Provide a tin or galvanized-iron speaking tube with mouthpieces (one in basement, one on first floor, and one on second floor where directed). All to be securely fastened to walls and made perfectly tight.

PAINTING.

The contractor must find and provide all the necessary materials of every description, including ladders, scaffolding, ropes, etc., for the performance of the work in a substantial and workmanlike manner, and of the best qualities of their respective kinds, and clean off all woodwork before priming it. Putty up all nail holes, joints, cracks and defects. Sandpaper smooth, and properly prepare the same before painting the second coat.

Priming.—All outside planed woodwork, such as casings, sash and frames to be primed as soon as in place with white lead and linseed oil. All exterior defects in woodwork must receive a strong coat of shellac before priming. All barge boards, posts, brackets, etc., to be rough for stain or smooth for paint, as the owner may direct.

Outside Painting.—Paint all the planed woodwork, two (2) coats of good white lead or zinc-white and linseed oil, mixed with colors to bring it to the shade to suit owner. All side wall and roof shingles, also all rough woodwork, and rough siding if any, to be given two good brush coats of Cabot's Creosote Shingle Stain. (Color to suit owner.)

Outside doors, if not of hardwood, to be painted two coats of zinc white and linseed oil. All outside hardwood doors to be stained and then given two coats of Pratt & Lambert's spar finishing varnish.

All tin and galvanized iron work to be given one coat of mineral paint, on under side before laying, then two coats of lead and oil on finished surface.

Inside Staining, Painting and Varnishing.—All open-grained woods are to receive one coat of paste wood filler (color to suit owner) and three coats of Pratt & Lambert's No. 38 preservative varnish, lightly sanded between coats. Then one coat of Pratt & Lambert's Dulkote.

All close-grained wood to receive one coat of Pratt & Lambert's acid stain (color to suit owner). The two coats of Pratt & Lambert's No. 38 preservative varnish lightly sanded between coats. Then one coat of Pratt & Lambert's Dulkote.

Tinting.—No ceiling or wall tinting in this job.

Floor Finish.—All floors except kitchen and bath to receive a coat of oil stain to match standing finish and two coats of Pratt & Lambert's No. 61 floor varnish. Kitchen and bathroom floors to receive a light oil stain and one coat of white grain alcohol shellac.

Picture Molding.—The painter is to finish picture mold to match finish of different rooms and of same materials as specified for other wood finish in the rooms in which it occurs.

PLUMBING.

This specification is meant to embrace all the materials and labor necessary for a complete system of plumbing, with all sewers, supplies, wastes and ventilating pipes for the same. All exposed pipes in rooms to be nickel-plated work, except where otherwise specified.

PLATE K.

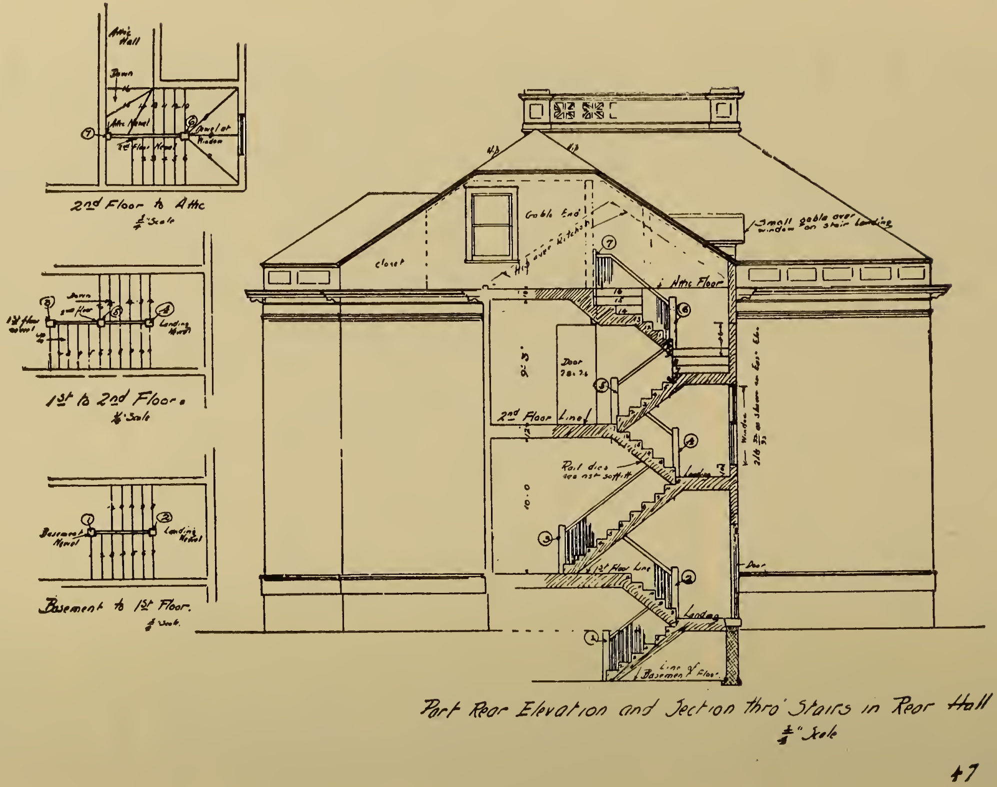

Attic Hall
Down
Attic Newel
2nd Floor Newel
Newel at Window
2nd Floor to Attic
¼" Scale
Down
2nd Floor
1st Floor Newel
Landing Newel
1st to 2nd Floor.
¼" Scale
Basement Newel
Landing Newel
Basement to 1st Floor.
¼" Scale
Closet
Gable End
Small gable over window on stair landing
Attic Floor
Door 7'0 x 2'6
9' 3"
2nd Floor Line
Rail dies see nst soffitt
10' 0
1st Floor Line
Landing
Door
Window
Line of Basement Floor
Part Rear Elevation and Section thro' Stairs in Rear Hall
¼" Scale
47

FIG. 259.
Residence for G. W. Wilson, Champaign, Ill. Brown Brothers, Architects, No. 808–9 Security Savings Bank Bldg., Cedar Rapids, Iowa.

Fixtures.—To consist of goods as specified below, and as shown on the drawings. Numbers all taken from Wolff's "H" catalogue. (Standard Manufacturing Company's or Mott's goods will be accepted, where design, size and quality of goods are the equal of Wolff's as specified.)

Kitchen Sink.—Fig. "H" 8052, to be 18×30″. Sink set on galvanized-iron sink brackets; supply with hot and cold water through two $\frac{5}{8}$″ N. P. finished Fuller Compression faucets in wall over sink, having the "Ideal" centrifugal wastepipe from wall to soil pipe, and 1″ vent pipe to trap.

Bathtub.—Wolff's Corona roll rim tub, Fig. "H" 6505, 5′ long, first grade enamel finish "Corona," complete, as described in catalogue.

Laundry Tubs.—Wolff's "W" 8158 complete, as described in catalogue. Provide wringer holder for these tubs.

Water Closet.—Where shown on plans, put in Wolff's syphon jet "W" 7085 water closet complete, as shown in catalogue. Provide the "never-split" seat for water closet. Seat to be cherry or birch and finished in ivory enamel. Make all necessary connections for supply and waste.

Lavatory.—Furnish and set where shown on plans Wolff's Fig. "H" 4050, "The Concord," complete, as described in catalogue. Make water connections to all fixtures with the city mains, and also make proper connections to hot-water pipes from heater.

Water Heater.—Provide and set in basement where directed one Ruud automatic gas heater. Make all necessary connections to water, vent and gas pipes in strict accordance with printed instructions furnished by the manufacturers, and to carry hot water to all fixtures except water closet in the building. Make proper connection to flue for vent where directed.

Contractor to make alternate bid on forty-gallon galvanized iron range boiler in kitchen to connect up with waterback in range and to all fixtures (except water closet) in the building.

Sewer.—From outside of wall run 4″ iron extra heavy soil pipe under house as directed, to connect to all fixtures in the building. Continue from outside of house, and run 4″ vitrified sewer tile below front line with cemented joints to cesspool. Sewer to have an even fall of at least $\frac{1}{4}$″ per foot, and where branches are made to different fixtures they must be made with "Y" joints. All vent, waste and supply pipes to be size and location as per local city ordinance.

Gas Piping.—Pipe for gas for Ruud heater and to all ceiling light outlets where shown on the drawings, using $\frac{3}{4}$″ pipe. All pipes are to be given the peppermint test, and to be installed in strict accordance with the local gas company's rules and regulations.

Waste Pipes.—All waste pipes connecting the different fixtures to main line of soil pipe are to be of extra heavy lead where they are not exposed in the room. All exposed work to be nickel-plated pipes as heretofore specified. All wastes below traps may be 2″ cast-iron soil pipe. Where connections are made to soil pipes they must be made by means of brass ferrules. Each fixture is to have a separate trap and is to have a separate vent pipe of sufficient size run independently through the roof and connected on main line of soil pipe at a point at least 2′ above the highest fixture in the building.

Water Supply.—The cold water will be taken from city mains and cistern through $\frac{3}{4}$″ galvanized iron pipe, and run in as direct manner as possible to the different fixtures in the building. Have a by-pass system of piping.

Hot water to be taken from heater in basement, and run to all the different fixtures (except water closet) in the building through $\frac{3}{4}''$ galvanized iron pipes. All the above supply pipes are to be galvanized iron, except the traps and connections to fixtures, which where exposed are to be brass, nickel-plated. Where iron and lead pipes are connected together it must be done with brass ferrules. All stop and waste cocks for the proper controlling and draining of these pipes must be provided where directed by architects. Make openings in walls of house where shown or directed and supply two sill cocks, Wolff's "H" 561 N. P. $\frac{3}{4}''$ with loose key for hose connections as directed.

Water Lift.—Provide and put in place a "Eureka" water lift in laundry where directed and make proper connections to city water and cistern for all fixtures.

All the above materials and workmanship to be first-class, put up by experienced workmen under the immediate supervision of the plumbing contractor, and when finished to be turned over to the owner free from leaks, and perfect in every respect. All to be subject to the acceptance of the local plumbing inspector. Contractor must furnish certificates of inspection, properly signed, before owner's final payment will be given.

All cellar floor drains are to be placed where directed and to comply with city ordinance.

Cesspool (if no sewer).—Where directed by owner build a brick cesspool 8″ in diameter and 10″ deep (or as deep as will be necessary to strike water or sand) with 4″ hard-burned brick walls laid in cement mortar (no brick in bottom). Arch cesspool over at top and provide a cast-iron ring and cover to be

2″ in diameter and 12″ below finished grade. Connect up to sewer in proper manner and trap the sewer just before entering cesspool. Contractor to give price per foot in depth over 10″.

Connect the soil pipe under water closet with 4″ standard cast-iron soil pipe, and continue the same as near as possible straight up through the roof, having openings and connections to different fixtures. All joints in soil pipe are to be packed with oakum, run with molten lead, and thoroughly caulked. No small vent pipe shall enter the main vent below the highest fixture in the building.

ELECTRIC WIRING.

General Notes.—No electric work shall be commenced until all plumbing roughing in is finished. All wiring to conform to the rules and regulations of the National Board of Fire Underwriters. All materials used and all work done must be strictly first class. Contractor must furnish certificates of inspection properly signed before architect's final certificate will be given.

Wires.—All wires to be carried to the several outlets as shown on plan, such wires to be of sufficient capacity to carry the number of lights indicated. All wires must be Habershaw, Okonite or Roebling white-core, rubber-covered wires. No splicing of wires will be allowed in the walls.

Switches.—All of the ceiling lights throughout the building, unless otherwise specified, shall be controlled on Hart Diamond H. push-button switches, located where shown and having plates finished to match the hardware of the room in which they occur. Place switch at top of cellar stairs to control light at foot of stairs in basement. Place switch on the inside of front door to control veranda light. There must be two switches in dining-room, where shown, to control lights in the center fixture. All of the bracket lights in the building must be controlled at the fixtures. See plans for the number and location of lights and all switches.

Outlet Boxes.—At each outlet place a steel outlet box, protected with compound to prevent corrosion (ceiling boxes without covers), and 4½″ diameter, all arranged to permit their being placed over gas-pipe outlet. Where no gas pipe is placed, boxes to have threaded fixture stubs; outlet boxes to be properly and firmly secured in position so that outer edge of box or cover will not project more than ¼″ beyond finished plaster.

Cutout Boxes.—At point where service enters building place a fireproof service cabinet; from this service box run one set of three (3) wire mains to cutout box to be placed where directed. In service box place a three-pole, single-throw fuse extension switch connected to mains, and three service wires of sufficient length to reach street wires, which must be connected to fused end of switch.

Cutout boxes to be of steel or cast iron set in wall or partitions, and furnished with asbestos-lined paneled door to match woodwork. In cutout boxes install Edison 3-wire 4-plug cutouts, with fused plugs complete.

Switches.—Each circuit to be provided with a double-pole indicating switch. Flush switches to be encased in iron boxes.

Circuits.—No more than eight lights are to be on any one circuit.

Capacity of Lights.—Number of light outlets are indicated on plans. Wires must be heavy enough to carry one 16-candle power lamp for each outlet.

Bells.—There must be bell in kitchen where directed, to be operated from front door push plate. Place floor receptacle and extension cord and table push button in dining-room to operate buzzer in kitchen. Use Sampson or La Clede batteries for all bells, and guarantee same for one year. All push buttons must be plated to conform to finish of hardware.

Telephone.—This contractor must do all interior wiring or telephone. Said telephone having outlets in rear hall or where shown on plans.

HEATING.

We recommend the Spencer Heater, the Capitol Boilers and the American Radiator Company's sectional cast-iron boiler and their cast-iron radiators. Any one of these heaters will be acceptable. Contractors bidding on this work must submit a schedule of radiation for each room and give their total number of feet of radiation to be used in the house. Also fill out their specification printed blanks complete, giving size of heater, etc., and submit same to owner along with their bid.

Contractor is to guarantee to heat house to 70° when coldest weather outside. All basement pipes are to be covered with asbestos and canvas covering, and all radiators are to be painted in colors to suit owner.

BROWN BROTHERS, ARCHITECTS,
No. 808–9 Security Savings Bank Bldg.,
Cedar Rapids, Iowa.

PLATE L.

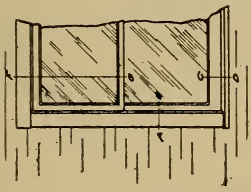
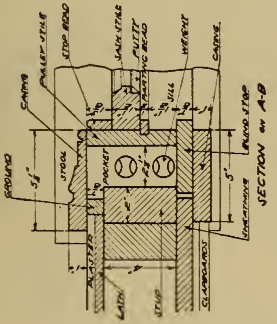
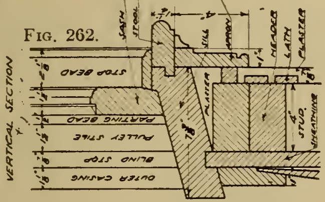
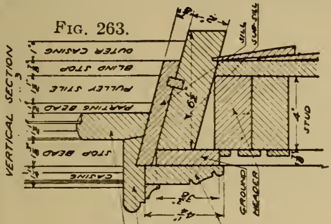
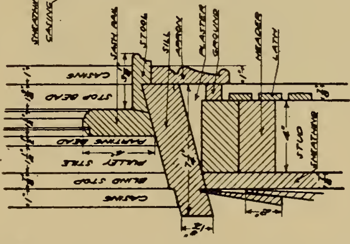


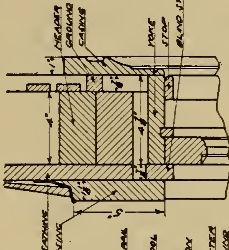
Fig. 260.

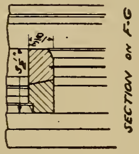

GROUND
CASING
STOOL
PULLEY STILE
STOP BEAD
SASH STILE
PUTTY
PARTING BEAD
SILL
WEIGHT
CASING
POCKET
PLASTER
LATH
STUD
CLAPBOARDS
SHEATHING
BLIND STOP
SECTION on A-B
Fig. 261.

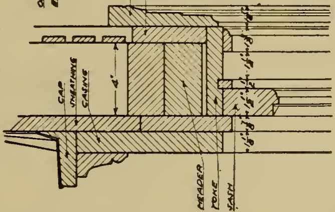

VERTICAL SECTION
STOP BEAD
PARTING BEAD
PULLEY STILE
BLIND STOP
OUTER CASING
SASH
STOOL
SILL
APRON
HEADER
LATH
PLASTER
STUD
SHEATHING
Fig. 262.

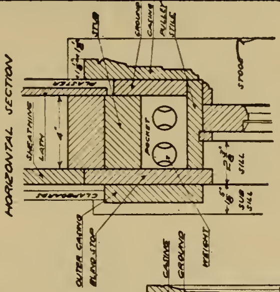

VERTICAL SECTION
OUTER CASING
BLIND STOP
PULLEY STILE
PARTING BEAD
STOP BEAD
CASING
SILL
SUB-SILL
STUD
GROUND
HEADER
Fig. 263.


CASING
STOP BEAD
PARTING BEAD
PULLEY STILE
BLIND STOP
CASING
SASH RAIL
STOOL
SILL
APRON
PLASTER
GROUND
HEADER
LATH
STUD
SHEATHING
SECTION on C-D
Fig. 264.


HEADER
GROUND
CASING
YOKE
STOP
BLIND STOP
SHEATHING
CASING
Fig. 265.


SECTION on F-G


VERTICAL SECTION
CAP
SHEATHING
CASING
HEADER
YOKE
SASH
Fig. 266.


HORIZONTAL SECTION
SHEATHING
LATH
PLASTER
STUD
GROUND
CASING
PULLEY STILE
POCKET
STOOL
SILL
SUB SILL
CLAPBOARDS
OUTER CASING
BLIND STOP
CASING
GROUND
WEIGHT
Fig. 267.

DETAILS
WINDOW FRAME
ARMOUR INSTITUTE of TECHNOLOGY
FEB 25, 1910 CHICAGO, ILL.
SCALE - 4" = 1 FOOT
HOURS PLATE
CHECKED BY A. S. GRAVES

Plate L. Fig. 260 shows the front elevation of a window. Figs. 261 to 267 give vertical and horizontal sections as indicated in Fig. 260.

Plate M. Figs. 268 to 273 inclusive, elevations and sections of gutters.

This plate is to be drawn according to directions given under "Problems."

Plate N. Figs. 274 and 275 show a Gothic style of lettering that is coming into common practice in architectural work drawings.

These plates are to be made according to directions given under "Problems."

In finishing the sections of the woodwork, prepare a dark shade of burnt sienna with a very little Chinese ink added and draw the wood sections free hand as given in the plate of standard sections on page 58. Use a Gillott pen No. 303.

PLATE M.

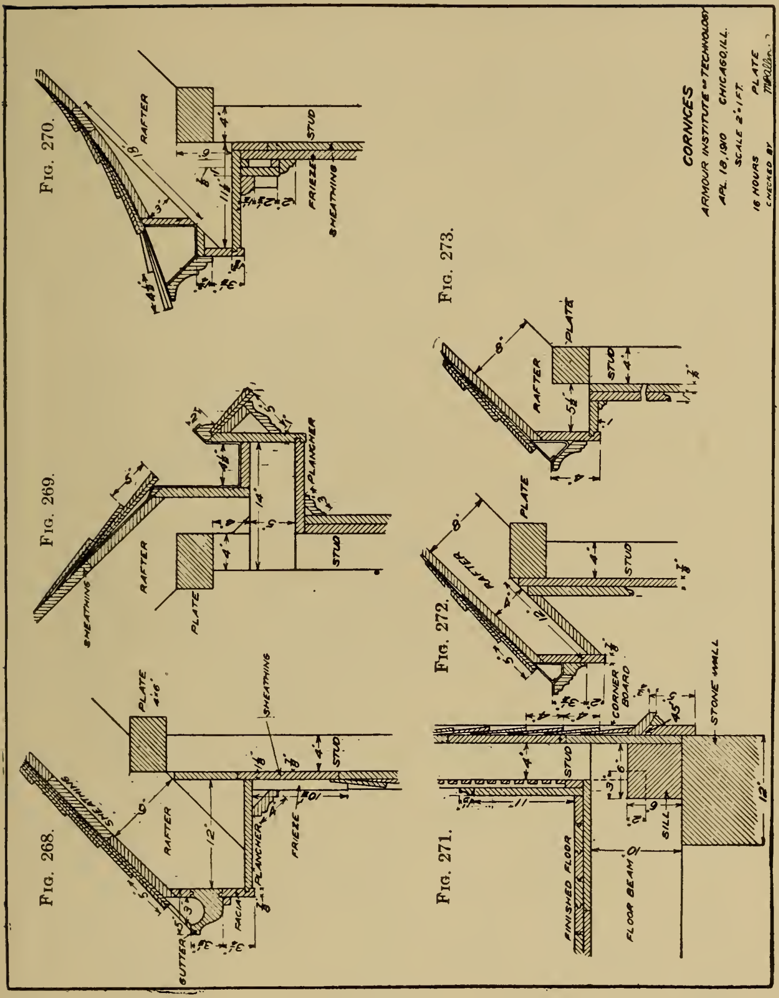


PLATE 4×6
SHEATHING
RAFTER
GUTTER
FACIA
PLANCHER
FRIEZE
STUD
PLATE
RAFTER
SHEATHING
PLANCHER
STUD
RAFTER
FRIEZE
SHEATHING
STUD
FINISHED FLOOR
FLOOR BEAM
SILL
STONE WALL
CORNER BOARD
STUD
RAFTER
PLATE
STUD
RAFTER
PLATE
STUD
CORNICES
ARMOUR INSTITUTE OF TECHNOLOGY
APL. 18, 1910 CHICAGO, ILL.
SCALE 2" = 1 FT.
16 HOURS PLATE
CHECKED BY

FIG. 268. FIG. 269. FIG. 270. FIG. 271. FIG. 272. FIG. 273.

PLATE N.

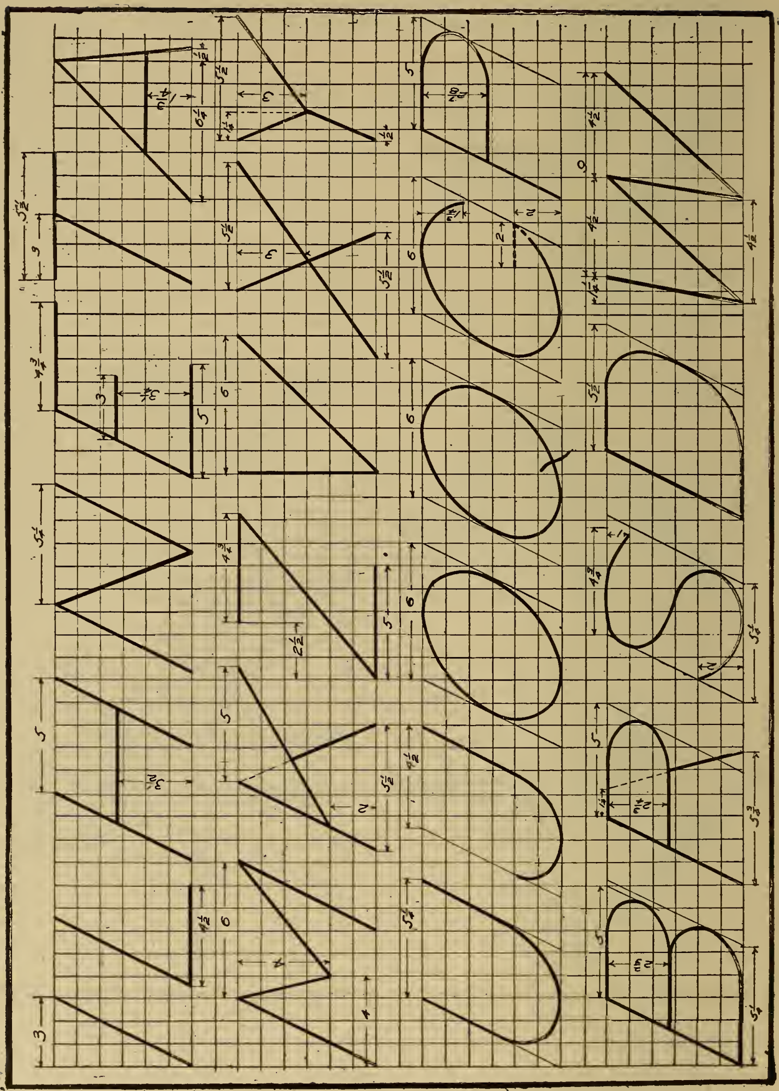


FIG. 274.

PLATE N.

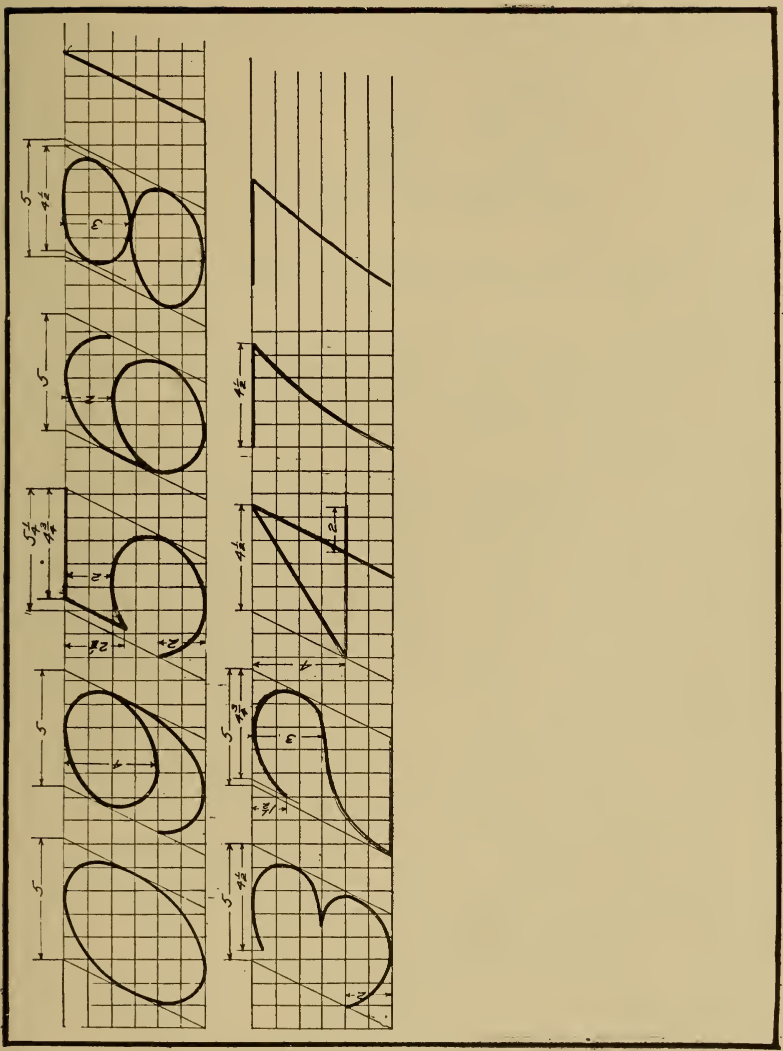

5
4½
3
5¼
4¾
2
2¼
4
¾

Fig. 275.

CHAPTER VIII.

SHEET METAL PATTERN DRAFTING.

STUDENTS who have completed Course I in Mechanical Drawing will find little difficulty in understanding the methods employed in solving the sixteen problems included in the following four plates of this course.

PROB. 1. It is required to make the pattern drawing of the rectangular box made of sheet tin shown by the isometric drawing Fig. 276. Fig. 277 shows the elevation and plan in orthographic projection and Fig. 278 the developed pattern. The $\frac{1}{4}''$ width added to the end of the sides are bent double as shown in Fig. 276 and are employed to stiffen the sides. A model of this box may be seen in the drafting room.

PROB. 2 is a conical piece made in two parts of thin planished iron. Fig. 279 is an isometrical drawing of the finished piece and Fig. 280 the orthographic views. Figs. 281 and 282 show the developed patterns with a $\frac{3}{16}''$ allowance on the edges for seams. See model in the drafting room.

PROB. 3 requires the drawing of a pattern for a flat-sided tapering box shown in isometric at Fig. 283. Figs. 284 and 285 show the orthographic views and the developed pattern respectively. The seams are to be soldered, therefore an allowance is not necessary in this case.

PLATE 29.

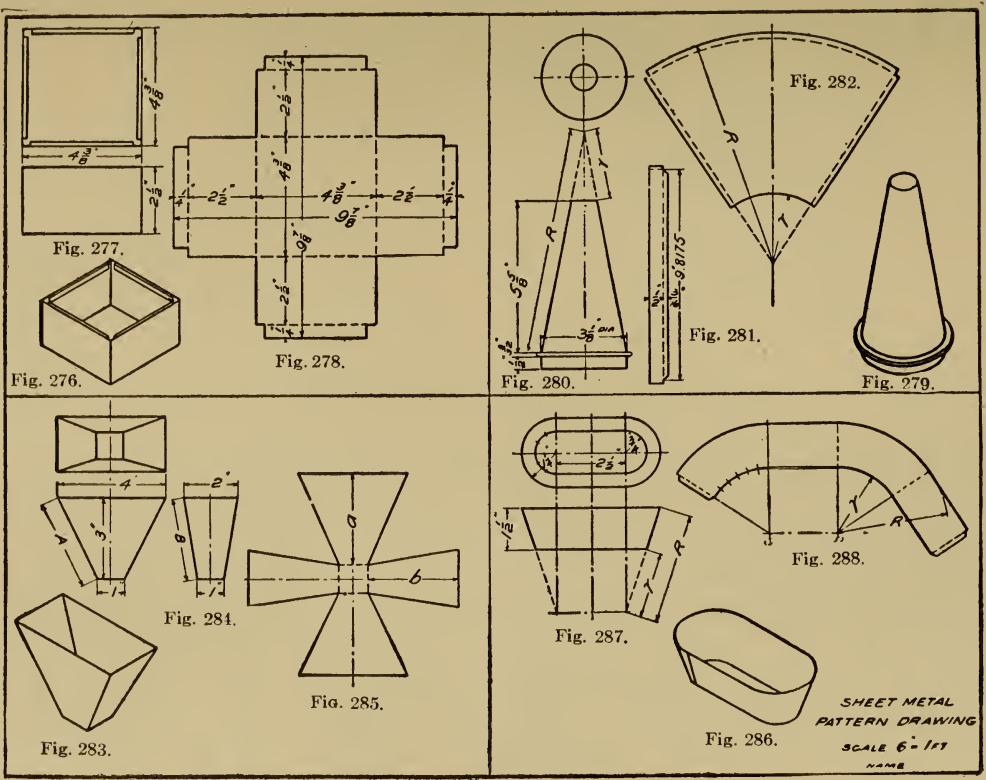


Fig. 276.

Fig. 277.

Fig. 278.

Fig. 279.

Fig. 280.

Fig. 281.

Fig. 282.

Fig. 283.

Fig. 284.

Fig. 285.

Fig. 286.

Fig. 287.

Fig. 288.

SHEET METAL
PATTERN DRAWING
SCALE 6" = 1 FT
NAME

4 3/8"
4 3/8"
2 1/2"
1/4"
2 1/2"
4 3/8"
2 1/2"
9 7/8"
R
r
5 5/8"
3 5/8" DIA
9.8175
4"
3"
A
2"
B
1"
a
b
2 3/4"
1/2"

PROB. 4. Make pattern in one piece of the oblong tapering article shown in isometric at Fig. 286. Fig. 287 gives the orthographic drawings with dimensions and Fig. 288 the developed pattern. Divide the small semicircle in the plan into six equal parts. Draw the two center lines, *C* and *D*, in Fig. 224, 2½″ apart. With centers, *C* and *D*, and radii *r* and *R* draw arcs. From lines, *C* and *D*, step off on the small arc the divisions found on small semicircle in plan. Through the last division draw radial lines from *C* and *D* and from the latter lay off the remaining side 2½″ long and add $\frac{3}{16}$″ allowance to each end as shown.

PROB. 5. Make the pattern drawing of a scale scoop assuming the two parts of which it is made to be segments of cylinders. Fig. 289 is the elevation of the scoop with one edge parallel to the horizontal plane, and the corresponding bottom edge making an angle of 40° with it.

Having drawn the scoop as given, draw the outline of the cylinders and at the end of the right hand one, draw a semicircle equal in diameter to the cylinder and divide the lower quadrant into six equal parts marking them 1 to 7. Through these points, 1, 2, 3, 4, etc., draw lines parallel to the axis of the cylinder cutting the upper edge and middle dividing line of the scoop in points 7, 6, 5, 4, 3, 2, 1′ and 1′, 2′, 3′, etc. respectively.

In laying out the development, Fig. 290, draw from the point 7′ a line perpendicular to the line 7′–7, and at a convenient distance from the latter draw the center line 1–1 and on the line 7′–1 in both directions, lay off the six divisions found on the semicircle. Through these divisions draw lines parallel to 1–1 and intersect these with perpendiculars drawn from the corresponding points of intersection of the scoop.

PROB. 6. Draw patterns of scale scoop whose elevation and

PLATE 30.

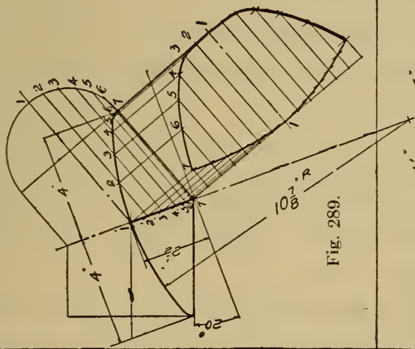

4"
4"
10 1/8" R
20°
20°
1
2
3
4
5
6
7

Fig. 289.

Fig. 290.

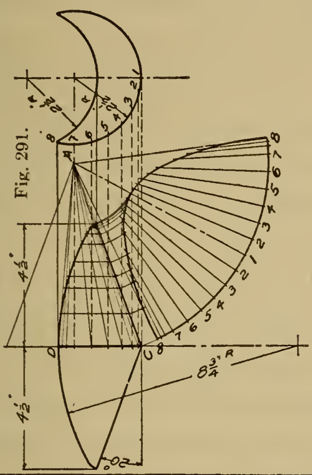

4 1/2"
4 1/2"
8 3/4" R
20°
A
B
C
D
1
2
3
4
5
6
7
8

Fig. 291.

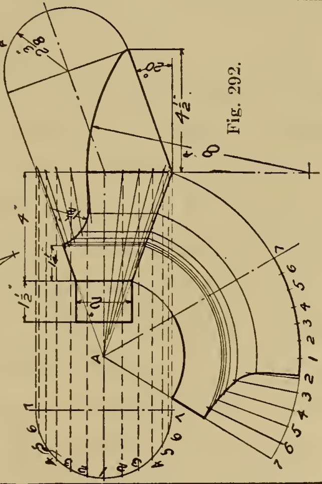

4"
1 1/2"
4 1/2"
2 3/8" R
8
20°
A
1
2
3
4
5
6
7

Fig. 292.

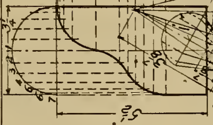

5 1/2"
1
2
3
4
5
6
7

Fig. 293.

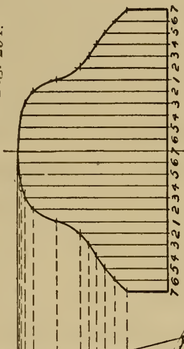

7 6 5 4 3 2 1 2 3 4 5 6 7 6 5 4 3 2 1 2 3 4 5 6 7

Fig. 294.

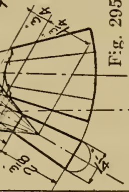


Fig. 295.

SHEET METAL
PATTERN DRAWING
SCALE 6" = 1 FT
NAME

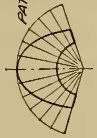


Fig. 296.

end view is shown in Fig. 291. This scoop is similar to that of Prob. 1 except that it is formed from the segments of cones. Draw the elevation and end view, divide the half of the end view as shown and through these divisions draw horizontals to cut the line *CD*. Draw the outline of the complete cone and from the intersecting points on *CD* draw elements to the apex of the cone. With the apex *A* as center and radius *AC* draw arc of circle 8–8 and lay off upon it from the center line *A*–1 in both directions the divisions 1 to 8 found on the end view.

Where the elements of the cone cut the upper edge of the scoop, drop perpendiculars to the contour element of the cone, thus finding the true distance of the points from the apex. With center *A* and each of these true lengths as radius draw arcs intersecting the corresponding elements in the development. Through these points draw the outline curve of the pattern.

PROB. 7. Make pattern drawings for a scoop with one end funnel-shaped, Fig. 292. The other end is made from the segment of a cone exactly like Prob. 1.

The funnel-shaped end is made from a cone, therefore the methods used in Probs. 1 and 2 can be applied here without any further directions.

PROB. 8. Draw pattern of grocer's scoop, Fig. 293. The body of scoop is cut from a cylindrical form as in Prob. 1. The methods are clearly shown in the drawing. Fig. 294 is the pattern of the body.

The handle is made up of two cone frustrums and the construction is similar to that used in Prob. 2. Figs. 295 and 296 are the handle patterns.

The student should be able to lay out these patterns without any further assistance.

TRIANGULATION.

Many articles in sheet metal work are of such irregular form that the methods employed in the preceeding problems cannot be used. It is therefore necessary under such conditions to obtain the development by measuring the whole surface part by part by means of triangles. Fig. 297 will illustrate the method of measuring the surface of an article of irregular form by means of triangles. If the article is symmetrical about its axis it will only be necessary to divide a quadrant of the top and bottom each with the same number of equal parts. Fig. 297 is an isometrical drawing of the irregular figure shown in Fig. 301. The quadrant 1 – 5 is divided into four equal parts, top and bottom. Join 1 – 1″, 2 – 2″, 3 – 3″, 4 – 4″ and 5 – 5″. Also join 1 – 2′, 2 – 2′, 2 – 3′, 3 – 3′, 3 – 4′ 4 – 4′, 4 – 5′ and 5 – 5′. These latter lines are the projections of the lines 1 – 2″, 2 – 2″, 2 – 3″, 3 – 3″, 3 – 4″, 4 – 4″, 4 – 5″, and 5 – 5″ and are used as the bases for the triangles laid out at Fig. 302 to find the true length of the lines joining the points in the top and bottom quadrants, for example 1′ – 2′, in Fig. 302 is the true length of 1 – 2′ on the plan of Fig. 301; 2″ – 2, Fig. 302, is the true length of 2′ – 2 in plan of Fig. 301, etc.

In laying out the development, Fig. 303, 1 – 1′ is taken directly from the elevation, Fig. 301, because it is in its true length being parallel to the vertical plane. The next step is to take 1′ – 2′, Fig. 301, as a radius and 1′, Fig. 303, as center, desrcibe an arc 1′ – 2′, then with 1′ – 2′, Fig. 302, as radius and 1, Fig. 303, as center, describe arc putting arc 1 – 2′ in the point 2′. With 1, Fig. 303, as center and 1 – 2, Fig. 302, as radius describe arc 1 – 2, Fig. 303, and with 2′, Fig. 303, as center and 2″ – 2, Fig. 302, as radius describe arc cutting arc 1 – 2 in the point 2 and so on, determining

PLATE 31.

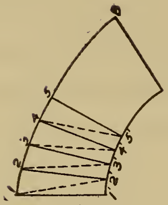

1
2
3
4
5
5'
4'
3'
2'
1'
6

Fig. 303.

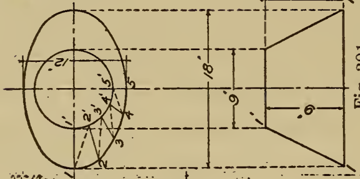

12"
18"
9"
6"
1
2
3
4
5
1'
2'
3'
4'
5'

Fig. 301.

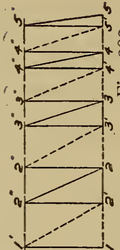

1
1'
2
2'
2"
3
3'
3"
4
4'
4"
5
5'

Fig. 302.

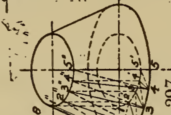


Fig. 297.

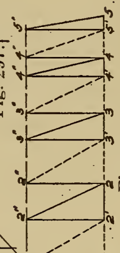

1'
2
2'
2"
3
3'
3"
4
4'
4"
5
5'

Fig. 299.

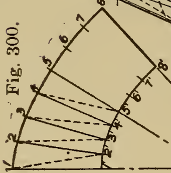


Fig. 300.

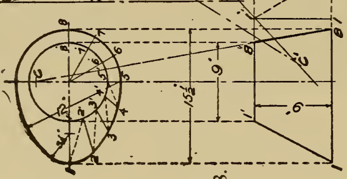


Fig. 298.

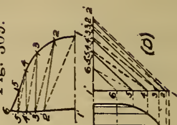


Fig. 309.

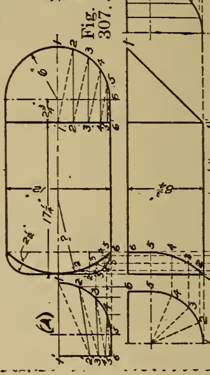

(A)
17¼"
12"
2¼"
8½"
1
2
3
4
5
6

Fig. 307.

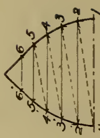


Fig. 310.

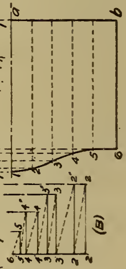


Fig. 308.

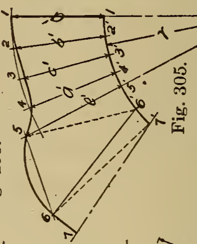

1
2
3
4
5
6
7
a
b
c
d
e
C

Fig. 305.

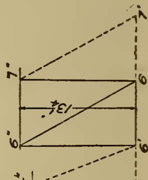

13¾"
11¼"
5
6
7
5'
6'
7'

Fig. 306.

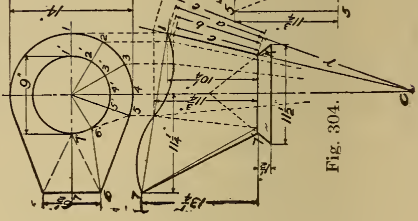

14"
9"
10¼"
11¼"
11½"
13¾"
C
1
2
3
4
5
6
7

Fig. 304.

the remaining points, 3, 4, 5, and 3′, 4′, 5′ in Fig. 303 in the same way. The remaining part of the semi-development 5 – *B*, Fig. 303, is a duplicate of that already found.

PROB. 9. It is required to make a pattern drawing for the article of irregular form shown in Fig. 298. Draw the plan and elevation as given and divide the upper and lower half into the same number of equal parts. Lay out the triangles, Fig. 299, and determine the development of the left quarter in the same manner as described above in reference to Fig. 297.

The right half of Fig. 298 is the half of a truncated cone, so that the development of that part is quite simple. Produce the line 8 – 8′ in the elevation, Fig. 298, to *C*, the apex of the cone, and when 5 – 5′, Fig. 300, has been drawn, produce it and lay off upon it from 5, 5 – *C*′ equal to 8 – *C* in Fig. 298. With *C*′ as center and *C*′ – 5′ and *C*′ – 5 as radii describe arcs 5′ – 8′ and 5 – 8 respectively, and complete the semi-development.

PROB. 10. Draw the pattern for the article of irregular form shown in Fig. 301. Sufficient directions for the solution of this problem were given in reference to Fig. 297.

PROB. 11. Make the pattern drawing for the coal scuttle shown in Fig. 304. Draw the elevation and plan as given. Observation will show that the form of the scuttle from 1 – 5 is part of a cone, so its development can be easily accomplished. The remaining portion will be developed by triangulation.

Lay out development as follows: with *r* and *r* + *a*, Fig. 304, as radii describe arcs 1 – 4 and 1′ – 5′, Fig. 305. On the curve 1′ – 5′, Fig. 305, lay off the points 2′, 3′, 4′, from the divisions of the small circle in the plan, Fig. 304. Through these points draw radial lines from *C*′ and make *a*′ *b*′ *c*′ *a*′ *e*′ equal in length to *abce* of the elevation, Fig. 304, and thus determine the points 1, 2, 3

4, 5, Fig. 305. Through the points found draw curve as shown. To determine points 6 and 7 construct the three triangles shown in Fig. 306. Then with center 5′, Fig. 305, and 5′ – 6′, Fig. 304, as radius describe arc and with point 5, Fig. 305, as center and 5″ – 6′, Fig. 306, as radius describe arc intersecting at 6′. With 5, Fig. 305, as center and 5 – 6, Fig. 304, as radius describe arc and with 6′, Fig. 305, as center and 6′ – 6 as radius describe arc intersecting at point 6. With the latter point as center, and 6 – 7 from the plan as radius describe arc, and with 6′ as center and 6′ – 7′ from the plan as radius describe arc. With 6, Fig. 305, as center and radius 7″ – 7′, Fig. 306, draw arc intersecting at 7′. With the latter point as center and 7′ – 7 from the elevation as radius draw arc intersecting in 7. Complete the development by joining 6 – 7 with a straight line and join 5 and 6 with an arc of a circle with radius equal to 5 – 6. Join 5′, 6′ and 7′ with an irregular curve. Develop the pattern for base.

PROB. 12. Draw patterns for bath tub given in plan and elevations in Fig. 307.

Draw plan, elevation, half-right end elevation and half-left end elevation in the order named. Draw also a half-lett end view from plan in first angle projection. The half pattern of the body may be developed at once by the method of parallel lines. Divide the left end view of tub into 4 equal spaces 1, 2, 3, 4, 5, and step these distances off on the line *ab* of the development and draw through the points parallel lines. From the points 6, 4, 3, 2, 1 *of* the elevation drop perpendiculars to intersect the corresponding lines in the development at 1, 2, 3, 4, 5, add 5, 6, and complete the half deveolpment of the body. The half development of the warped surface of the foot can now be obtained in the following manner: Divide the quarter circle of the corner in the plan into 4 equal parts in the points 2′, 3′, 4′, 5′, 6′, and project these points to the line 1′ – 6 of the end view. Project the points 1, 2, 3, 4, 5 to the curved line of the end view. Lay out the triangles to obtain the true lengths of the measuring lines. The heights are obtained from the end view at *A*, the bases from the plan. The true lengths of the upper edge of the pattern are taken from the plan while the radii for the respective arcs of the lower edge must be taken from the outline of the pattern for the body: Thus the radius 1 – 2, Fig. 309, is taken from 1 – 2, Fig. 308, and so on. The radius 1 – 2′, Fig. 309, is taken from 1 – 2′ in (*A*), 2 – 2′ in Fig. 309 from 2 – 2 (*B*), 2 – 3′ in Fig. 309 from 2″ – 3′ in (*B*) and so on. The development of the pattern of the head piece is found in a similar way. The line 1 – 1′, Fig. 310, can be taken directly from 1 – 1′ in the elevation as it is shown there in its true length. To find the true lengths of the remaining lines the heights of the triangles are laid off on the line 1′ – 2′ from the respective lines in the plan, for example 1′ – 2′ is equal to 1′ – 2 in the plan and so on. The bases of the triangles are projected from the end view in 6, 5, 4, 3, 2, 1, and each hypothenuse drawn in order. The arcs 1 – 2, 2 – 3, etc., and 1′ – 2′, 2′ – 3′, etc., are taken from the corresponding distances in the plan. The development may now be completed by drawing arcs, using each hypothenuse of the triangles in their proper order as radius.

Prob. 13. Draw the development for a two-piece pipe elbow, Fig. 311.

Draw the plan and elevation to the dimensions given and develop the half of one piece by the method shown. The methods used in finding the developments in this plate are so clearly shown that the student should not require any detail directions.

PLATE 32.

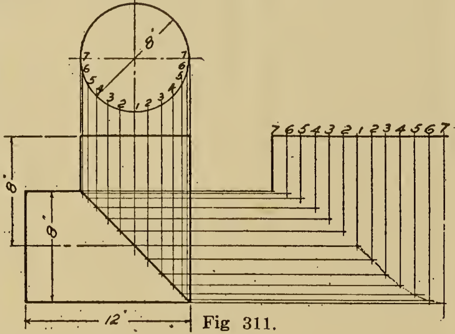

8"
7 6 5 4 3 2 1 2 3 4 5 6 7
7 6 5 4 3 2 1 2 3 4 5 6 7
8"
8"
12"

Fig 311.

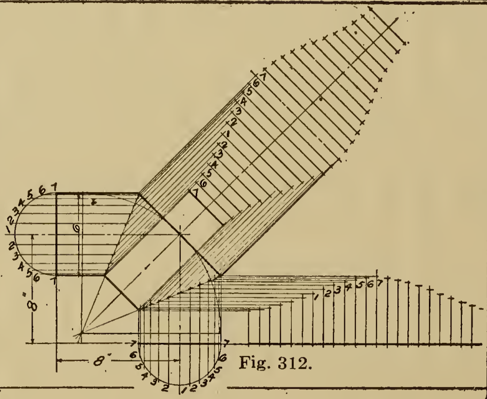

1 2 3 4 5 6 7
6
8"
8"
1 2 3 4 5 6 7
7 6 5 4 3 2 1 2 3 4 5 6 7

Fig. 312.

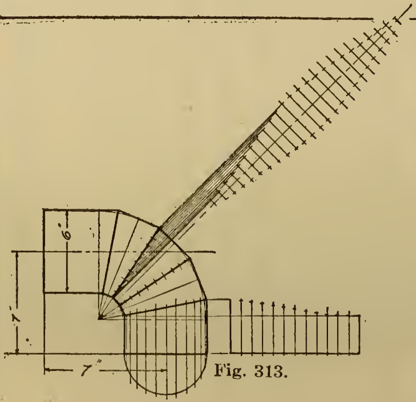


Fig. 313.

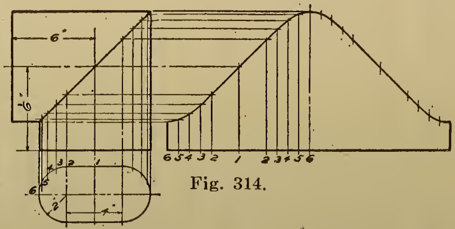

6"
6"
6 5 4 3 2 1 2 3 4 5 6
4"
2"

Fig. 314.

Prob. 14. Develop the necessary patterns for a three-piece elbow. Fig. 312.

Prob. 15. Develop the necessary patterns for a five-piece elbow. Fig. 313.

Prob. 16. Draw the pattern of a two-piece oblong pipe elbow. Fig. 314.

CHAPTER IX.

ELEMENTARY MACHINE DETAILS, INCLUDING SCREWS, NUTS, BOLTS, KEYS, COTTERS AND GIBS, COUPLING SPRINGS, ETC.

A Screw is a helical projection or thread formed upon a cylinder and is the most common device used in mechanical combinations. It is employed in the construction of machinery for producing pressure contact and transmitting motion. When

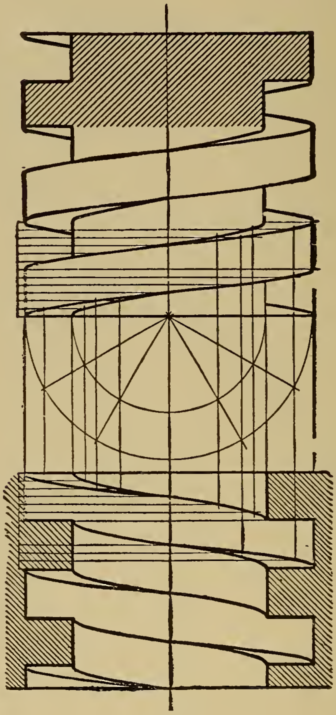


FIG. 315.

the thread of an external screw is made to fit into the corresponding hollow of an internal screw (Fig. 315) the latter is termed its nut.

The Pitch of a Screw-thread is the lineal distance its nut would advance along the axis in one turn. In a single-threaded screw the pitch is the distance between the centres of two consecutive threads measured in the direction of the axis, in a double-threaded screw it is the distance from centre to centre of every alternate thread, and in a triple-threaded screw it is a distance that will embrace three threads. For screw-fastenings, instead of giving the pitch the number of threads per inch of screw is given—for example, a bolt of 1″ diameter has generally 8 threads per inch; this means that the bolt has a single thread wound around it 8 times for every inch of its length.

Right- and Left-handed Screws.—Screws are made right- and left-handed, of which the right-handed are the more common and are distinguished by their nuts advancing along the screws when turned in the direction in which the hands of a watch revolve. On a drawing the right-handed screws are distinguished by the threads inclining upwards towards the right hand when the screws are in a vertical position, as in Fig. 315. When a nut with a right-handed thread is shown in section the direction of the threads in the nut is the opposite to the threads on the screw.

The Nominal Diameter of a Screw is the diameter over the tops of the threads and is equal to the diameter of the cylinder upon which the thread is cut. It is the area of the nominal diameter that is considered when estimating the shearing strength.

The Effective Diameter is the diameter at the bottom of the thread and is equal to the diameter of the hole in the nut before its threads are cut. Unless when the bolts are subjected to a shearing stress, it is the area of the effective diameter that is considered in estimating their strength.

The Depth of the Thread is the distance measured perpendicularly to the axis of the screw from the top to the bottom of the thread.

NOTATION.

d = nominal diameter of bolt;
d_1 = effective diameter of bolt;
δ = depth of thread;
δ_1 = total depth of V;
p = pitch of thread;
n = number of threads per inch.

The Forms of Screw-threads in general use in machine construction are represented in Figs. 316–320. The V thread is adopted on all screw-fastenings because of the shearing strength of the threads and frictional holding power, which is due to the normal pressure on the thread being inclined to the axis of the screw. This normal force N, Fig. 316. may be resolved into two components, one L parallel to the

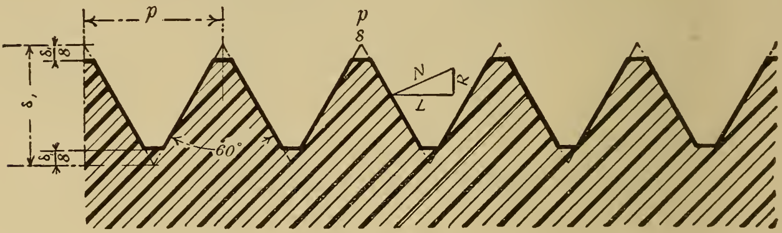


FIG. 316.

axis of the screw, and the other R at right angles to it. L represents the load carried by the thread and R the force tending to burst the nut; therefore the greater the angle of the V the greater will be the normal component or bursting force, and, the friction being proportional to the normal force, it will increase with the angle of the V. Of the forms of V threads shown two (Figs. 316 and 317) are in common use in the United States for bolts and nuts.

The Sellers or United States Standard, a section of which is shown in Fig. 316, has been adopted by the U. S. Government, the Railway Master Mechanics' Association, the Master Car-builders' Association, and many of the principal manufactories in this country. The sides of this thread form an angle of 60° with each other, and are $\frac{1}{8}$ of δ_1 short of meeting at a sharp point at the tops and bottoms, which makes the sides of the thread in length equal to $\frac{3}{4}$ of the pitch, and the depth of thread δ will be expressed by the formula

$$\delta = \tfrac{3}{4} \times p \sin 60^\circ = 0.65p. \quad . \quad . \quad . \quad . \quad (1)$$

The effective diameter will then be

$$d_1 = d - 2\delta = d - 1.3p = d - \frac{1.3}{n}. \quad . \quad . \quad (2)$$

The relation between the pitch and the diameter will be expressed by the formula

$$p = 0.24\sqrt{d + 0.625} - 0.175. \quad . \quad . \quad . \quad (3)$$

The number of threads per inch is

$$n = \frac{1}{p} = \frac{1}{0.24\sqrt{d + 0.625} - 0.175}. \quad . \quad . \quad (4)$$

The table of proportions on page 70 has been deduced from the preceding formulæ. A difference, however, may be found between the formulæ and the table in the number of threads per inch, as the table has been modified to avoid as far as practicable troublesome combinations in the gears of screw-cutting machines.

Exercise 1.—Draw 6 threads in sectional outline, of the *Sellers thread* (Fig. 316), suitable for a screw 6″ in diameter. *Scale three times full size.*

Construction.—Begin by drawing a horizontal line in the upper left-hand corner of the paper ¾″ down from the border-line, and a vertical line about ¾″ in from the left-hand border-line. Then find the pitch *p* by the formula (3), and from where the two lines you have just drawn intersect mark off with the scale on the horizontal line 6 points a distance apart equal to the pitch as found by the formula. Through these points with the 30° triangle draw the V's. Complete the pencilling by dividing the depth of the V into 8 equal divisions, and cut off one division at the top and bottom of each thread.

The Sharp V Thread, shown in Fig. 317, is one of the forms of threads that were in use before the Sellers thread

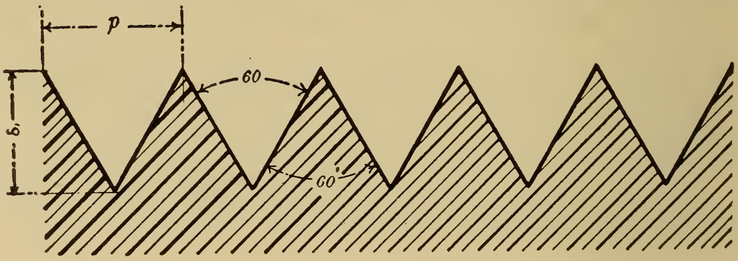


FIG. 317.

was adopted as the U. S. standard, and is still used, although condemned by all progressive engineers. This thread is the same as the Sellers thread except that the sides are made to meet at a sharp point at the top and bottom, which makes the sides of the thread equal in length to the pitch p, and the depth of the thread δ_1 will be expressed by the formula

$$\delta_1 = p \sin 60° = 0.866p. \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The effective diameter of the bolt (d_1) will then be expressed by the formula

$$d_1 = d - 2 \times 0.866p = d - 1.732. \quad . \quad . \quad (6)$$

Now, comparing the effective diameters, we have:

U. S. threads $d_1 = d - 1.3p.$ . . . . (2)
V threads $d_1 = d - 1.732p.$ . . . . . . (6)

This serves to show that with an equal pitch the *effective diameter* of the screw having a U. S. standard thread is greater than one with a sharp V thread. While the latter form of thread materially diminishes the strength of the bolt, the sharp point adds very little strength to the thread. A further objection to this form of thread is the variation in depth of the threads due to the wear of the sharp points on the taps and dies used in producing them.

The Whitworth V Thread, an outline section of which is shown in Fig. 318, is the British standard, and is generally adopted on all screw-fastenings in British machine construction. It has the sides of the V inclined to each other at an angle of 55°, and has an amount rounded off at the top and bottom equal to $\frac{1}{6}$ of the total depth of the V. *The table of* *dimensions for Whitworth screws* (page 70) has been deduced from the following formulæ. The total depth of the V

$$\delta_1 = 0.5 \cot 27\tfrac{1}{2}^\circ = 0.96p. \quad . \quad . \quad . \quad . \quad (7)$$

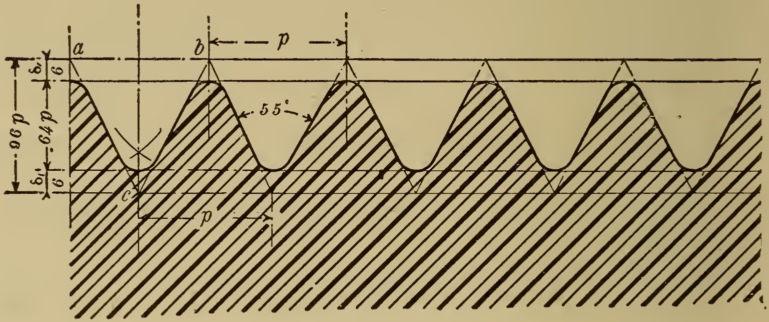


FIG. 318.

The depth of the finished thread

$$\delta = \tfrac{2}{3} \times 0.96p = 0.64p. \quad . \quad . \quad . \quad . \quad (8)$$

The pitch $$p = 0.08d + 0.04. \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Number of threads per inch

$$= \frac{1}{p} \quad \text{and} \quad p = \frac{1}{n}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The diameter at the bottom of the thread will be given by the formula

$$d_1 = d - 2 \times 0.64p = d - \frac{1.28}{n}. \quad . \quad . \quad . \quad . \quad (11)$$

Exercise 2.—Draw 6 threads of the *Whitworth form of thread* (Fig. 318). Pitch ½″. *Scale three times full size.*

Construction.—At a suitable distance below the drawing of the Sellers thread draw two horizontal lines parallel to each other and a distance apart equal to 0.96p. On the upper line mark off a distance *ab* equal to the pitch. Bisect *ab* and draw the bisecting line to cut the lower parallel line at the point *c*. Join *ca* and *cb*, which will be inclined to each other at an angle of 55°. Mark off the pitch from *b* along the upper line, and from *c* along the lower line, to give the required number of threads. Complete the pencilling by rounding off the sharp points of the V.

The Square Screw-thread.—The form of thread which is invariably called the square thread is really a rectangle, the depth of the thread being equal to $0.485p$ and its width equal to $0.5p$. However, it is usual and accurate enough to make it square upon the drawing. *On screws of the same diameter the pitch of a square-threaded screw is usually made equal to twice the pitch of one with a V thread; therefore the square thread will have only half the amount of material at the bottom of the thread that the V thread has to resist the shearing action of the load. As the bearing-surfaces of this screw are perpendicular to the axis, and the force applied parallel to it, there will be no bursting force upon the nut; and as the reaction is nearly equal to the load on the square-threaded screw, there will be less friction than there is under the same conditions with a V thread; consequently the square thread is best adapted for transmitting motion when the load has to be moved in opposite directions.

The Knuckle or Rounded Screw-thread is a modification of the square thread in which the top and bottom of each thread are made semicircular, as shown in Fig. 379. This form of thread is used for rough work and can be readily thrown in and out of gear with a portion of a nut.

The Buttress Screw-thread is a combination of the V and square threads, one side being perpendicular, and the other inclined at an angle of 45° to the axis of the screw, and has an amount cut from the top and bottom of each

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* Klein gives $p = .08 + .09d$, $d_1 = .91d - .08$.

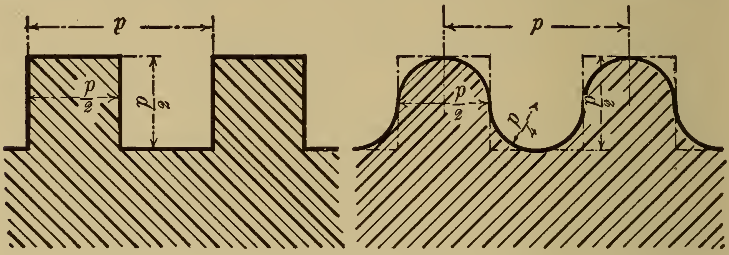


Fig. 319.

thread equal to $\frac{1}{8}$ of the total depth of the thread, as shown in Fig. 320. This form of thread can be used only when the pressure is on that side of the thread which is at right angles to the axis of the screw.

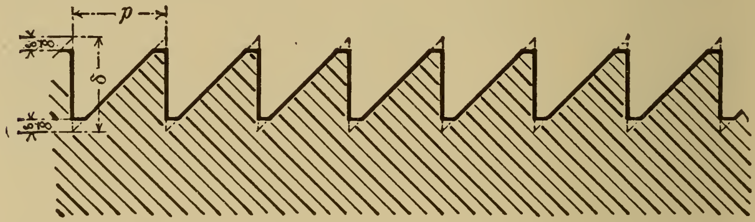


Fig. 320.

Exercise 3.—Draw the sectional outline of the square, knuckle, and buttress threads shown in Figs. 319 and 320. Pitch 1″. *Scale twice full size.*

Pipe-threads.—Previous to the year 1862 no common system had been agreed upon for the form or proportions of pipe-threads. Since that time, owing to the efforts of the late Robert Briggs, C.E., who proposed formulæ and tables for the dimensions of pipes and pipe-threads, a standard

TABLE 1.

STANDARD DIMENSIONS OF WROUGHT-IRON WELDED TUBES.

(Briggs Standard.)

Diameter of Tube.			Thickness of Metal.	Screwed Ends.	
Nominal Inside.	Actual Inside.	Actual Outside.		Number of Threads per Inch.	Length of Perfect Screw.
Inches.	Inches.	Inches.	Inch.	No.	Inches.
⅛	0.270	0.405	0.068	27	0.19
¼	0.364	0.540	0.088	18	0.29
⅜	0.494	0.675	0.091	18	0.30
½	0.623	0.840	0.109	14	0.39
¾	0.824	1.050	0.113	14	0.40
1	1.048	1.315	0.134	11½	0.51
1¼	1.380	1.660	0.140	11	0.54
1½	1.610	1.900	0.145	11½	0.55
2	2.067	2.375	0.154	11½	0.58
2½	2.468	2.875	0.204	8	0.89
3	3.067	3.500	0.217	8	0.95
3½	3.548	4.000	0.226	8	1.00
4	4.026	4.500	0.237	8	1.05
4½	4.508	5.000	0.246	8	1.10
5	5.045	5.563	0.259	8	1.16
6	6.065	6.625	0.280	8	1.26
7	7.023	7.625	0.301	8	1.36
8	7.982	8.625	0.322	8	1.46
9	9.000	9.625	0.344	8	1.57
10	10.019	10.750	0.366	8	1.68

Taper of conical tube-ends, 1 in 32 to axis of tube (¾ in. per foot total taper).

system has been generally used and was formally adopted by the manufacturers of wrought-iron pipes and boiler-tubes and by the Association of Manufacturers of Brass and Iron Steam-, Gas-, and Water-work of the United States.

The following is an extract from a paper by Mr. Briggs as given in the report of the American Society of Engineers:

"The thread employed has an angle of 60°; it is slightly rounded off, both at the top and at the bottom, so that the height or depth of the thread, instead of being exactly equal to the pitch, is only four fifths of the pitch, or equal to $0.8\frac{1}{n}$, if n be the number of threads per inch. For the length of tube-end throughout which the screw-thread continues perfect the empirical formula used is $T = (0.8D + 4.8) \times \frac{1}{n}$, where D is the actual external diameter of the tube throughout its parallel length, and is expressed in inches. Further back, beyond the perfect threads, come two having the same taper at the bottom, but imperfect at the top. The remaining imperfect portion of the screw-thread, furthest back from the extremity of the tube, is not essential in any way to this system of joint; and its imperfection is simply incidental to the process of cutting the thread at a single operation.

Exercise 4.—Draw a section of a pipe-screw (Fig. 321) for a wrought-iron pipe 8″ in diameter. *Scale five times full size.*

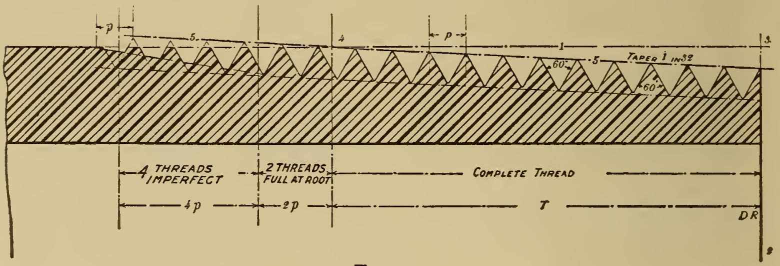


FIG. 321.

Construction.—Draw two lines parallel to each other at a distance apart equal to the thickness of metal as given in the table; then draw the vertical line 2 to represent the end of the pipe, and from 2 along the line 1 mark off 3, 4, equal to T. *Taper 1 in 32 means an inclination of 1 unit in height to every 32 units in length.* From the point 4 draw the line 5 at the required inclination. On the line 5 from where it intersects 2 mark off points at a distance apart equal to the pitch, and through these points with the 30° triangle draw the threads. The bottoms of the last 4 threads are cut off by drawing a line from the bottom of the last thread that is full at the bottom to a point on the surface of the pipe which is a distance beyond the screwed part equal to the pitch.

Screw-thread Conventions.—The method of drawing screws to represent their true form is shown in Fig. 315, but it is quite obvious that it is unnecessary for the draftsman to perform this lengthy geometrical construction to indicate each screwed piece upon the drawing. Instead he adopts some convention suitable to the class of drawing he is making that can be quickly drawn and is generally understood to represent a screw-thread. Fig. 322, No. 1, shows a convention for a double V thread; No. 2, a single V thread; No. 3, a single square thread; No. 4, a single left-hand V thread; No. 5, a double right-hand square thread; No. 6, any V thread of small diameter; No. 7, any thread of very small diameter. The method adopted on rough drawings and sketches is shown at No. 7. The dotted lines indicate the bottom of the thread, and the distance they extend along the piece the length of the

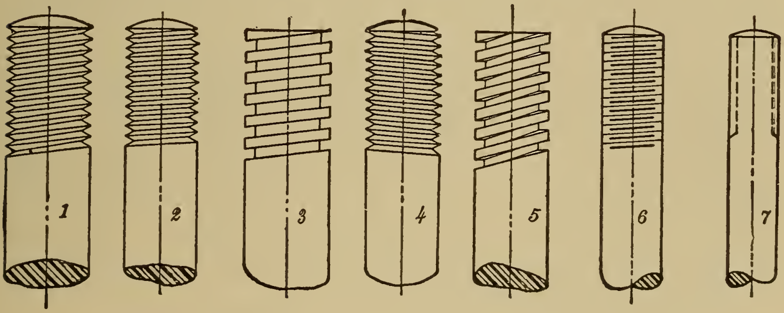


FIG. 322.

screwed part. At Nos. 1, 2, 4 are shown conventions adopted upon finished drawings to represent threaded screws of a large diameter and wide pitch. There are various ways of improving the appearance of this convention: one is by shading the lower lines of each thread, as shown in Fig. 324; and another method is to fill in completely the under side of the thread. At No. 6 is shown a method adopted on working drawings to represent screw-threads upon pieces of a small diameter or large screws drawn to a small scale. Here the narrow lines indicate the top and the wide lines the bottom of the screw-thread. When a very long screw has to be represented upon a drawing, as is often the case with the square-threaded screw, a few threads are drawn at the beginning of the screwed part, and the length of the screw is indicated by dotted lines drawn from the bottoms of the threads.

The Nut.—The most common application of the screw for producing contact pressure is the bolt, used in conjunction with a nut, of which there are different forms. The form most in use is the hexagonal (Fig. 324).

The standard proportions for hexagonal nuts are:

$H =$ height $=$ diameter of bolt (d).

$F =$ distance across the flats $= 1\frac{1}{2}d + \frac{1}{8}$ of an inch.

$D =$ distance across the corners $= (1\frac{1}{2}d + \frac{1}{8}'')\ 1.155$.

Fig. 323 shows the true form of the curves when the end of the nut is machined to form a part of a sphere or cone. This rounding or bevelling off of the corners is called chamfering. The radius r of the chamfering is made from $1\frac{1}{2}d$ to $2d$, and the angle a is made from 60° to 45° with the axis of the nut. *When representing nuts upon a drawing they should* *always be drawn to show the distance across the angles,* as in the elevation Fig. 323.

Exercise 5.—Draw the true curves of a hexagonal nut for a bolt 6″ in diameter when the top of the nut is chamfered

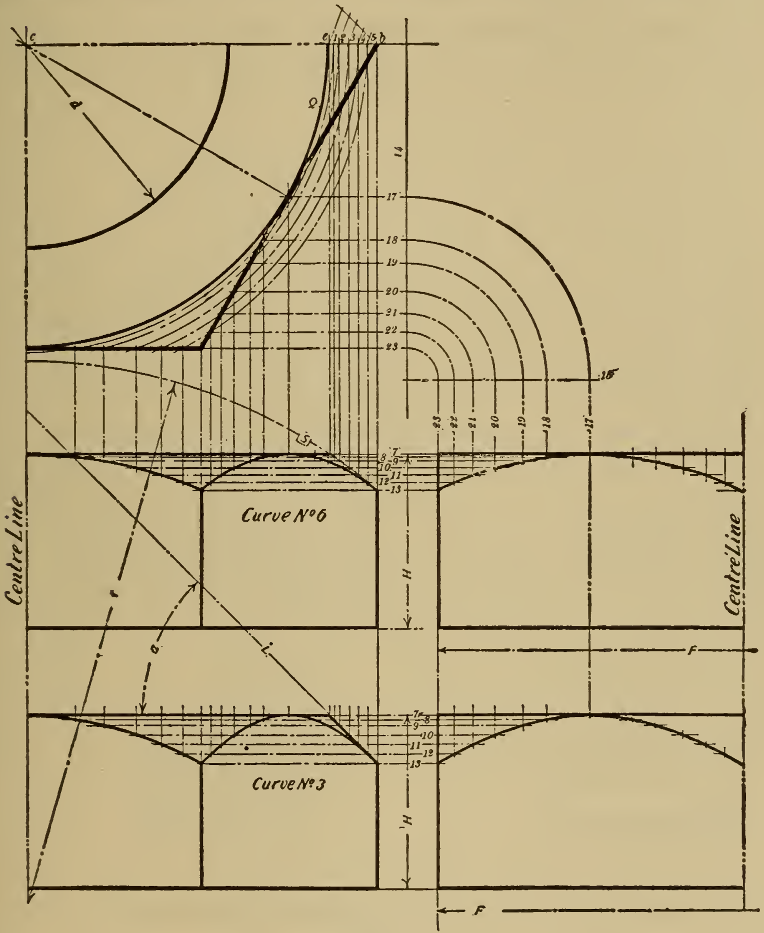

c
d
b
Q
14
17
18
19
20
21
22
23
16
Sr
Curve N°6
Centre Line
Centre Line
H
F
r
a
Curve N°3
H′
F
7
8
9
10
11
12
13

FIG. 323.

off to form a part of a sphere with a radius $r = 1\frac{1}{2}$ times the diameter of the bolt (d), and when the chamfering is a part of a cone the side of which makes an angle of 45° with the axis of the nut, as shown in Fig. 323.

Construction.—Begin with the plan, first locating the centre *c*, and with *c* as a centre and a radius equal to $\frac{1}{2}d$ draw the quadrant representing the hole in the nut, and from the same centre and a radius equal to half the distance across the flats *F* draw the quadrant *Q*, and on this quadrant circumscribe a part of a hexagon with the 30° triangle and T square, as shown in Fig. 324. Draw the part elevations and end views, and with *r* as a radius and the centre on the centre line draw the arc *S*, which represents the spherical chamfer, and on the lower elevation draw the angle *a*. Divide *eb* into any number of divisions, say 6, at points 1, 2, 3, 4, 5*d*. Where perpendicular lines drawn through these points intersect the arc *S* and line *L* draw the horizontal lines 7, 8, 9, 10, 11, 12, 13, and with *c* as a centre and radii *c*1, *c*2, *c*3, *c*4, *c*5 draw arcs, and from where these arcs intersect the inclined face of the nut draw vertical lines to intersect the lines 7, 8, 9, 10, etc. These points of intersection will be points of the curve on the side face of the nut. The curve of the front face will be an arc of a circle. To find the curves on the side view draw a line 15 say $\frac{1}{2}''$ below and parallel to the lower face of the nut in plan, and a perpendicular line 14 half an inch to the left of the end view; where the arcs drawn through the points 1, 2, 3, etc., from the centre *c* cut the inclined face of the nut in plan draw horizontal lines to intersect the line 14; and with a centre at the intersection of the lines 14 and 15 revolve the lines 17, 18, 19, 20, 21, 22, 23 on to the line 15 and draw perpendicular lines through the points of intersection. The line 17 revolved will be the centre of the nut face on the end view, and the intersection of the lines 17, 18, 19, 20, 21, 22, 23 with the horizontal lines 7, 8, 9, 10, 11, 12, 13 will be points on one half of the required curve. To complete the curve, with a centre at the intersection of the line 17 and the top of the nut mark with the compasses corresponding points on the other side of the line 17.

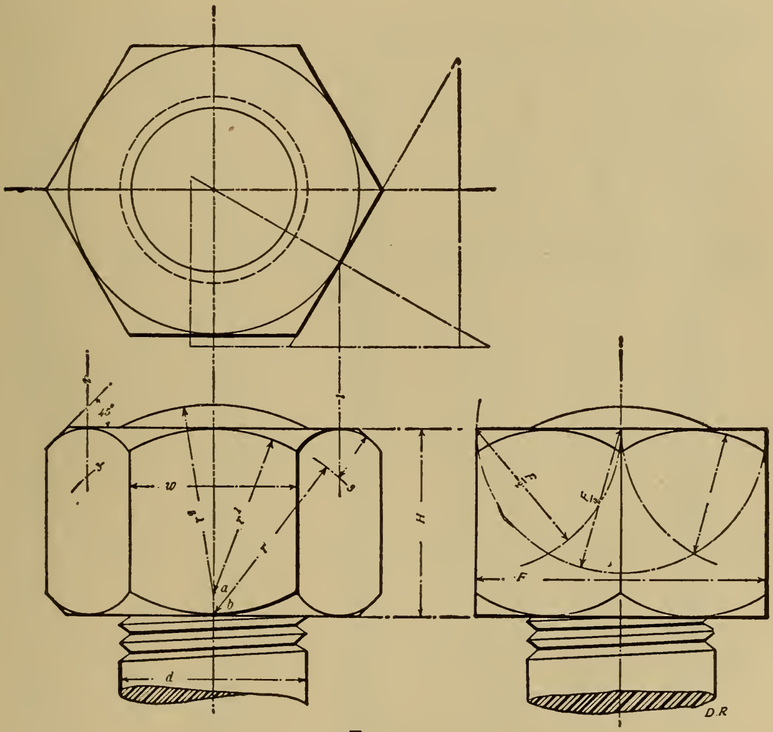


FIG. 324.

A Conventional Method of representing large nuts on drawings is shown in Fig. 324. In this representation the curves of the nut are arcs of circles and the corners are chamfered off at an angle of 45° to the axis of the nut.

TABLE

UNITED STATES STANDARD OF

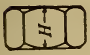
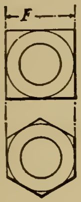
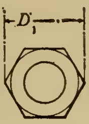
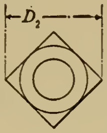
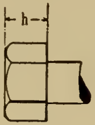
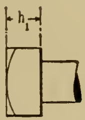
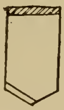
Screw-threads.

Diameter of Screw.	Number of Threads per Inch.	Diameter at Bottom of Threads.	Area at Bottom of Threads in Square Inches.	Area of Bolt Body in Square Inches.
¼	20	.185	.027	.049
5/16	18	.240	.045	.077
⅜	16	.294	.068	.110
7/16	14	.344	.093	.150
½	13	.400	.126	.196
9/16	12	.454	.162	.249
⅝	11	.507	.202	.307
¾	10	.620	.302	.442
⅞	9	.731	.420	.601
1	8	.837	.550	.785
1⅛	7	.940	.694	.994
1¼	7	1.065	.893	1.227
1⅜	6	1.160	1.057	1.485
1½	6	1.284	1.295	1.767
1⅝	5½	1.389	1.515	2.074
1¾	5	1.491	1.746	2.405
1⅞	5	1.616	2.051	2.761
2	4½	1.712	2.302	3.142
2¼	4½	1.962	3.023	3.976
2½	4	2.176	3.719	4.909
2¾	4	2.426	4.620	5.940
3	3½	2.629	5.428	7.069
3¼	3½	2.879	6.510	8.296
3½	3¼	3.100	7.548	9.621
3¾	3	3.317	8.641	11.045
4	3	3.567	9.963	12.566
4¼	2⅞	3.798	11.329	14.186
4½	2¾	4.028	12.753	15.904
4¾	2⅝	4.256	14.226	17.721
5	2½	4.480	15.763	19.635
5¼	2½	4.730	17.572	21.648
5½	2⅜	4.953	19.267	23.758
5¾	2⅜	5.203	21.262	25.967
6	2¼	5.423	23.098	28.274

Note.—The above table gives the sizes of the rough nuts and bolt-heads. The finished

2.

SCREW-THREADS, BOLTS, AND NUTS.

Nuts.				Heads.		Tap Drill.
						
¼	½	37/64	7/10	¼	¼	3/16
5/16	19/32	11/16	10/12	5/16	19/64	¼
⅜	11/16	51/64	63/64	⅜	11/32	5/16
7/16	25/32	9/10	1 7/64	7/16	25/64	23/64
½	⅞	1	1 15/64	½	7/16	13/32
9/16	31/32	1⅛	1 23/64	9/16	31/64	15/32
⅝	1 1/16	1 7/32	1½	⅝	17/32	17/32
¾	1¼	1 7/16	1 49/64	¾	⅝	⅝
⅞	1 7/16	1 21/32	2 1/32	⅞	23/32	¾
1	1⅝	1⅞	2 19/64	1	13/16	27/32
1⅛	1 13/16	2 3/32	2 9/16	1⅛	29/32	31/32
1¼	2	2 5/16	2 53/64	1¼	1	1 3/32
1⅜	2 3/16	2 17/32	3 3/32	1⅜	1 3/32	1 3/16
1½	2⅜	2¾	3 23/64	1½	1 3/16	1 9/32
1⅝	2 9/16	2 31/32	3⅝	1⅝	1 9/32	1 13/32
1¾	2¾	3 3/16	3 57/64	1¾	1⅜	1½
1⅞	2 15/16	3 13/32	4 5/32	1 7/8	1 15/32	1⅝
2	3⅛	3⅝	4 27/64	2	1 9/16	1¾
2¼	3½	4 1/16	4 61/64	2¼	1¾	1 31/32
2½	3⅞	4½	5 31/64	2½	1 15/16	2 3/16
2¾	4¼	4 29/32	6	2¾	2⅛	2 7/16
3	4⅝	5⅜	6 17/32	3	2 5/16	2⅝
3¼	5	5 13/16	7 1/16	3¼	2½	2 29/32
3½	5⅜	6 7/64	7 39/64	3½	2 11/16	3 1/32
3¾	5¾	6 21/32	8⅛	3¾	2⅞	3 11/32
4	6⅛	7 3/32	8 41/64	4	3 1/16	3 19/32
4¼	6½	7 9/16	9 3/16	4¼	3¼	3 13/16
4½	6⅞	7 31/32	9¾	4½	3 7/16	4 1/32
4¾	7¼	8 13/32	10¼	4¾	3⅝	4 9/32
5	7⅝	8 27/32	10 49/64	5	3 13/16	4½
5¼	8	9 9/32	11 23/64	5¼	4	4¾
5½	8⅜	9 23/32	11⅞	5½	4 3/16	4 31/32
5¾	8¾	10 5/32	12⅜	5¾	4⅜	5 7/32
6	9⅛	10 19/32	12 15/16	6	4 9/16	5 7/16

sizes are: $H = d - 1/16''$; $F = 1\frac{1}{2}d + 1/16''$: $h = d - 1/16''$; $h_1 = \frac{1\frac{1}{2}d + 1/16''}{2}$.

The A. L. A. M. Standard Screws and Nuts.—The form of the screw thread is the U. S. Standard as shown in Fig. 316. The number of threads per inch for the A. L. A. M. bolts and nuts is given in Table 3. Bolts and nuts are made of steel, whose tensile strength must not be less than 100,000 pounds per square inch and elastic limit not less than 60,000 pounds per square inch.

TABLE 3.

A. L. A. M. STANDARD SCREWS AND NUTS.

d	Number of Threads.	*F*	*G*	*H*	*K*	*M*	*Q*
$\frac{1}{4}$	28	$\frac{3}{8}$	$\frac{5}{64}$	$\frac{9}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{16}$
$\frac{5}{16}$	24	$\frac{1}{2}$	$\frac{5}{64}$	$\frac{21}{64}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{16}$
$\frac{3}{8}$	24	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{13}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{32}$
$\frac{7}{16}$	20	$\frac{11}{16}$	$\frac{1}{8}$	$\frac{29}{64}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{32}$
$\frac{1}{2}$	20	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{9}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{5}{32}$
$\frac{9}{16}$	18	$\frac{7}{8}$	$\frac{5}{32}$	$\frac{39}{64}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{5}{8}$	18	$\frac{15}{16}$	$\frac{5}{32}$	$\frac{23}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$
$\frac{11}{16}$	16	1	$\frac{5}{32}$	$\frac{49}{64}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$
$\frac{3}{4}$	16	$1\frac{1}{8}$	$\frac{5}{32}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$
$\frac{7}{8}$	14	$1\frac{1}{4}$	$\frac{5}{32}$	$\frac{29}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$
1	14	$1\frac{7}{16}$	$\frac{5}{32}$	1	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$

The length of the threaded portion of the bolt should be about $1\frac{1}{2}$ times the diameter.

Bolt heads and plain nuts are flat chamfered, as in Fig. 324.

Castle nuts have a spherical chamfer, as in Fig. 324.

Bolts and nuts are finished with what is known as screw makers' "semi-finish."

Screws, screw heads, and plain nuts are left soft, while castle nuts are case-hardened.

The body diameter of the screw is one-thousandth of an inch (.001) less than the nominal diameter. The clearance between top and bottom of threads in nuts is correct when the top is made from two-thousandths to three-thousandths of an inch large.

Nuts are made to fit without apparent shake. Fig. 325 shows the A. L. A. M. bolt and castle nut. The facing under the head and nut is made equal in diameter to the distance across the flats and is made so that the scratching of the nut when it is being screwed on to a finished surface will not show. It also increases the pressure per square inch.

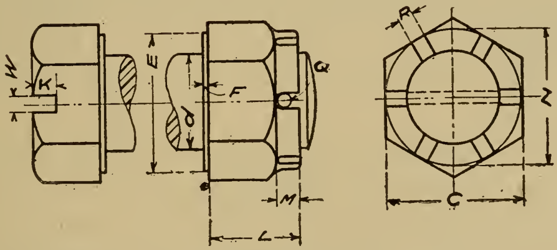


FIG. 325.

Split Pins, when made of a uniform diameter from wire of a semicircular cross-section and provided with a head, as in Fig. 326, are used for preventing pieces from separating, while allowing a slight motion in the direction of the axis of the piece that they pass through. The method of drawing split pins is clearly shown in Fig. 326. The diameter of the pin, in proportion to the diameter d of the piece it passes through, may be $= .05d + .13$, taking the nearest size in $\frac{1}{16}''$.

Taper Pins, shown in Fig. 327, are used for securing one piece to another in a fixed position. They are sometimes split at the small end, and opened out in the same manner as the ordinary split pin, to prevent slacking back. The diameter of the tapered pin at the large end, in proportion to the diameter (*d*) of the piece through which it passes, may be made = .06*d* + .13 and taking the nearest size from Table 4 (page 249).

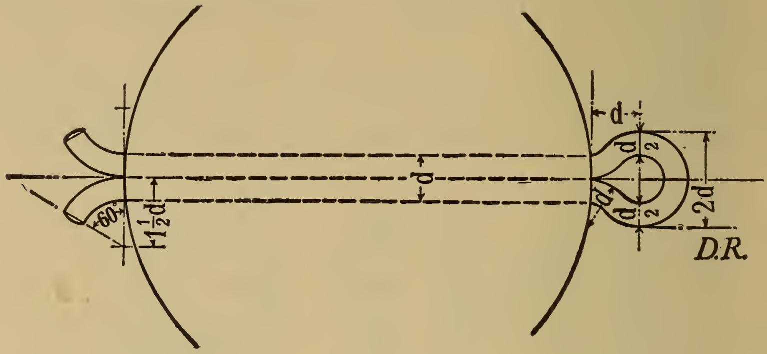


FIG. 326.

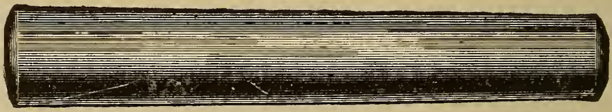


FIG. 327.

Keys are employed to connect wheels, cranks, cams, etc., to shafting transmitting motion by rotation. They are generally made of wrought iron or steel, and are commonly

TABLE 4.

STANDARD STEEL TAPER-PINS.

Taper one-quarter inch to the foot.

Number........	0	1	2	3	4	5	6	7	8	9	10
Diameter at large end	.156	.172	.193	.219	.250	.289	.341	.409	.492	.591	.706
Approximate fractional sizes	5/32	11/64	3/16	7/32	¼	19/64	11/32	13/32	½	19/32	23/32
Longest limit of length	1	1¼	1½	1¾	2	2¼	3¼	3¾	4½	5¼	6

rectangular, square, or round in cross-section. The form of key in general use is made slightly tapered and fits accurately into the key-way, offering a frictional holding power against the keyed piece moving along the shaft. The groove or part where the key fits on the shaft, and the groove into which it fits on the piece it is holding is called the key-bed, key-way or key-seat. For square or rectangular keys, when the keyed piece is stationary on the shaft, the bottom of the groove on the shaft is parallel to the axis, while that of the groove in the piece it is securing is deeper at the one end than the other to accommodate the taper of the key.

Keys may be divided into three classes: 1. Concave or saddle key; 2. flat key; 3. sunk key.

Saddle Key.—This form of key has parallel sides, but is slightly tapered in thickness and is concaved on the under side to suit the shaft, as shown in Fig. 328. As the holding power depends entirely upon the frictional resistance, due to the pressure of the key on the shaft, the saddle key is only adapted for securing pieces subjected to a light strain. When this key is used for securing a piece permanently, the taper is usually made 1 in 96, but when employed on a piece requiring to be adjusted, such as an eccentric, the taper is increased to 1 in 64 to allow the key to be more easily loosened.

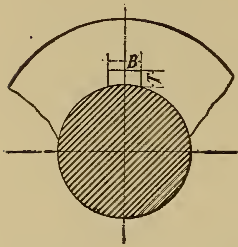


FIG. 328.

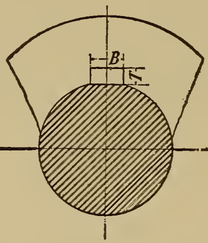
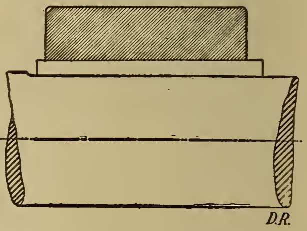


FIG. 329.



Flat Key.—This form of key, Fig. 329, differs from the saddle key in that it rests on a flat surface filed upon the shaft. It makes a fairly efficient fastening, but as it drives by resisting the turning of the shaft under it, there is a tendency to burst the keyed-on piece.

TABLE 5.

DIMENSIONS OF SADDLE AND FLAT KEYS.

D	1	1¼	1½	1¾	2	2½	3	3½	4	5	6	7	8
B	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1	1⅛	1⅜	1½	1¾
T	3/16	3/16	3/16	¼	¼	5/16	5/16	⅜	⅜	7/16	½	9/16	⅝

Sunk Keys are so called because they are sunk into the shaft and the keyed-on piece, Fig. 330, which entirely prevents slipping. For engine construction they are usually rectangular in cross-section and made to fit the key-seat on all sides. When subjected to strains suddenly applied, and

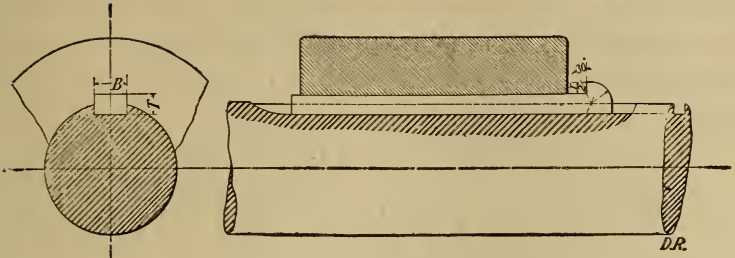


FIG. 331.

in one direction, they are placed to drive as a strut, diagonally, as in Fig. 331.

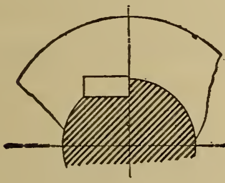


FIG. 330.

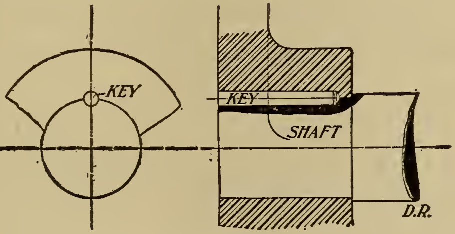


FIG. 332.

The following table, taken from Richards's "Machine Construction," agrees approximately with average practice:

TABLE 6.

DIMENSIONS OF RECTANGULAR SUNK KEYS.

D	1	1¼	1½	1¾	2	2½	3	3½	4	5	6	7	8
B	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1	1⅛	1⅜	1½	1¾
T	5/32	3/16	¼	9/32	5/16	⅜	7/16	½	⅝	11/16	13/16	⅞	1

In mill-work, for fastening pulleys, gear-wheels, couplings, etc., to shafting they are made slightly greater in depth than breadth. For machine tools they are generally square in cross-section. The following table gives the sizes of keys used by Wm. Sellers & Co. both for shafting and machine tools:

TABLE 7.

	″	″	″	″	″	″	″	″	″
D	1½	1¾	2	2¼	2½	2¾	3	3¼	3½
B	5/16	5/16	7/16	7/16	9/16	11/16	11/16	11/16	11/16
T	⅜	⅜	½	½	⅝	¾	¾	¾	¾
	″	″	″	″	″	″	″	″	″
D	4	4½	5	5½	6	6½	7	7½	8
B	13/16	13/16	13/16	15/16	15/16	15/16	1$\frac{1}{16}$	1$\frac{1}{16}$	1$\frac{1}{16}$
T	⅞	⅞	⅞	1	1	1	1⅛	1⅛	1⅛

Round Keys.—Taper-pins (Fig. 332) are sometimes used as keys to prevent rotation where a crank or wheel is shrunk on to the end of a shaft or axle. Round keys are used in such a case because of the ease in forming the key-way, which is simply a tapered round hole drilled half into the shaft and half into the shrunk-on piece. The standard proportions of the pins are given on page 249. The size at the large end nearest to $\frac{1}{4}$ of the shaft diameter may be used for this purpose.

Fixed Keys are used when it is undesirable to cut a long key-way on the shaft to allow the key to be driven into place after the keyed-on piece is in position. The fixed key is sunk into the shaft, as in Fig. 333, and the keyed-on piece is driven into position after the key is in place.

When a keyed-on piece has to be adjusted to different positions on the shaft, to avoid the trouble of drawing a tight key in and out, it is made to slide in the key-way, and the keyed-on piece is held against moving along the shaft by means of set-screws, as shown in Fig. 334.

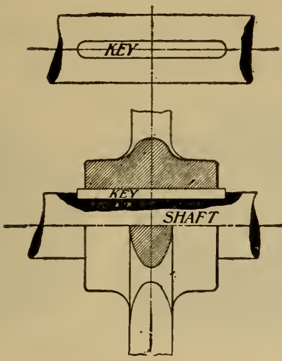


FIG. 333.

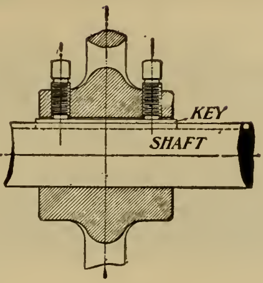


FIG. 334.

Sliding Feather Key.—This system of keying secures the piece to the shaft, to transmit motion of rotation, and at the same time allows the keyed-on piece to move along the shaft. They may be secured to the keyed piece and slide in a groove on the shaft, as in Fig. 335, or secured to the shaft and slide in the groove in the keyed piece, as in Fig. 333. The dimensions for this form of key may be taken from Table 7.

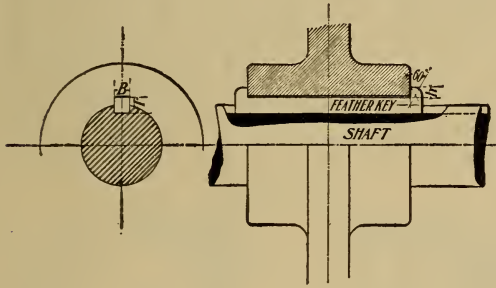


FIG. 335.

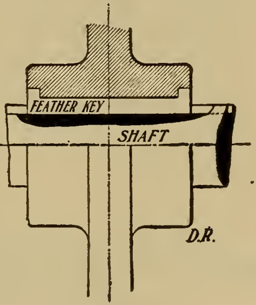


FIG. 336.

Woodruff Keys.—This system of keying (Fig. 337) is used for machine tools, or wherever accurate work is of first importance. With this form of key, as the key rights itself to the groove in the keyed-on piece, there is no danger of the work being thrown out of true by badly fitted keys, and, being deep in the shaft, it cannot turn in the key seat

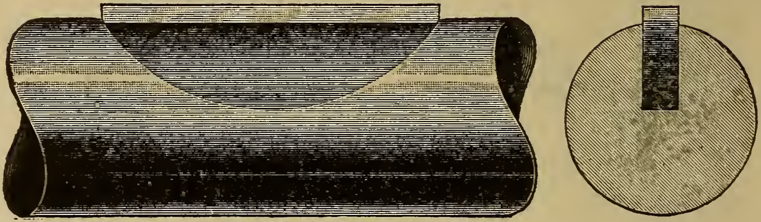


FIG. 337.

TABLE 8.

No.	*A*	*B*	*C*	*D*	*d*	No.	*A*	*B*	*C*	*D*	*d*
6	$\frac{5}{8}$	$\frac{5}{32}$″	$\frac{5}{64}$″	$\frac{1}{16}$″	$\frac{7}{8}$″ or $\frac{15}{16}$″	21	$1\frac{1}{4}$″	$\frac{1}{4}$″	$\frac{1}{8}$″	$\frac{5}{64}$	$1\frac{1}{2}$″ to $1\frac{5}{8}$″
8	$\frac{3}{4}$	$\frac{5}{32}$′	$\frac{5}{64}$″	$\frac{1}{16}$″	$\frac{7}{8}$″ or $\frac{15}{16}$″	22	$1\frac{3}{8}$″	$\frac{1}{4}$″	$\frac{1}{8}$″	$\frac{3}{32}$	$1\frac{9}{16}$′ to $1\frac{5}{8}$″
10	$\frac{7}{8}$″	$\frac{5}{32}$′	$\frac{5}{64}$″	$\frac{1}{16}$″	$\frac{7}{8}$″ or $\frac{15}{16}$″	23	$1\frac{3}{8}$″	$\frac{5}{16}$″	$\frac{5}{32}$″	$\frac{3}{32}$″	$1\frac{11}{16}$″ to $1\frac{3}{4}$″
11	$\frac{7}{8}$″	$\frac{5}{32}$″	$\frac{5}{64}$″	$\frac{1}{16}$″	1″	24	$1\frac{1}{2}$″	$\frac{1}{4}$″	$\frac{1}{8}$″	$\frac{7}{64}$″	$1\frac{11}{16}$″ to $1\frac{3}{4}$″
13	1″	$\frac{3}{16}$″	$\frac{3}{32}$′.	$\frac{1}{16}$″	$1\frac{1}{8}$″	25	$1\frac{1}{2}$″	$\frac{5}{16}$″	$\frac{5}{32}$″	$\frac{7}{64}$″	$1\frac{13}{16}$″ to $2\frac{1}{2}$″
17	$1\frac{1}{8}$″	$\frac{7}{32}$″	$\frac{7}{64}$″	$\frac{5}{64}$″	$1\frac{1}{4}$″ or $1\frac{5}{16}$″	26	$2\frac{1}{8}$″	$\frac{3}{16}$″	$\frac{3}{32}$″	$\frac{17}{32}$″	2″ to $2\frac{3}{4}$″
20	$1\frac{1}{4}$″	$\frac{7}{32}$″	$\frac{7}{64}$″	$\frac{5}{64}$″	$1\frac{3}{8}$″ or $1\frac{7}{16}$″	G	$1\frac{1}{2}$′	$\frac{3}{8}$″	$\frac{3}{16}$″	$\frac{7}{64}$″	2″ to $2\frac{1}{2}$″

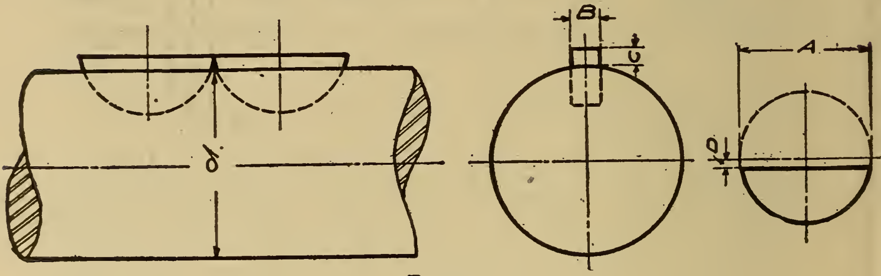


FIG. 338.

The "Woodruff" key, reaching deeper into the shaft than one of ordinary construction, is more firmly imbedded, and hence capable of standing a much greater strain.

It is impossible for a Woodruff key to roll over in its seat, as is often the case with an ordinary key. In case of an accident, Woodruff keys have been known to shear off without damaging pulley or shaft, where an ordinary key of the same width would roll in the seat and destroy both pulley and shaft. Whitney Manufacturing Company.

COTTERS

are keys employed to connect pieces which are subjected to tensile and compressive forces. They are driven transversely through one or both of the connected pieces and transmit power by a resistance to shearing at two cross-sections. The cotters are usually made rectangular in cross-section, and the ends rounded, as shown in Fig. 339.

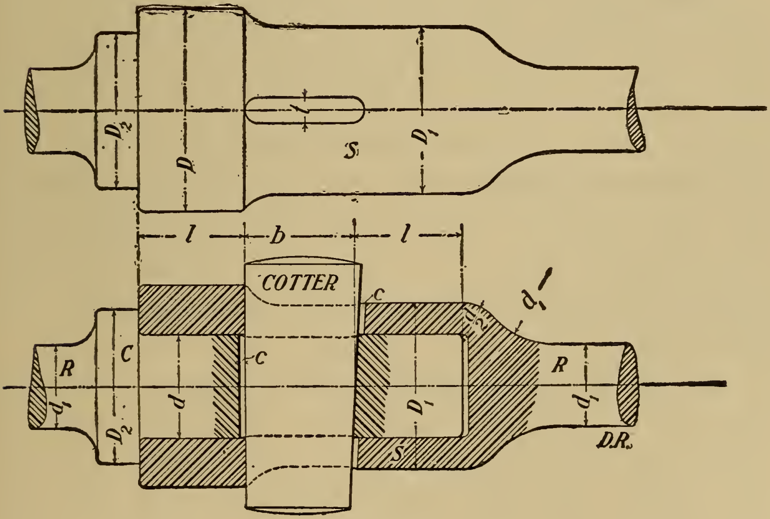


FIG. 339.

The cotter-way with the rounding ends is generally adopted, as it is easier to make, which is done by drilling two holes of a diameter equal to the thickness of the cotter and cutting out the metal between them. Again, this form of cotter-way does not weaken the cottered pieces to quite the same extent as when the corners are left sharp. The cotters, however, are not so easily fitted into cotter-ways with round ends, and for that reason some engineers make the cotters of rectangular cross-section, fitted into corresponding cotter-ways.

Taper of Cotters.—When cotters are employed as a means of adjusting the length of the connected pieces, or for drawing them together, they are made tapered in width, as in Fig. 339, but when used as a holding-piece only, the sides are parallel. When tapered cotters depend upon the friction between their bearing-surfaces for retaining them in position, the taper should not be more than 1 in 24 (½″ per foot), but where special means are employed for holding the cotter against slacking, the taper may be made as great as 1 in 6 (2″ per foot).

Forms and Proportions of Cotter-joints.—When the fastening is subjected to tension only, the arrangement shown in Fig. 339 is used for securing two pieces together by means of a cotter. Fig. 339 shows a method of fastening two rods, *R* and *R′*, together to resist thrust and tension. The joint is made by fitting the end of the rod *R* into a socket *S* formed on the end of the rod *R′*, and through the socket and rod end driving a cotter until the collar *C* bears against the socket end.

As a cotter-joint is proportioned to withstand the greatest longitudinal force transmitted by the rod, all parts will therefore be proportional to the diameter d_1 of the rod, unless where the dimensions of the rod are increased to insure stiffness. The following proportions are in accordance with good practice:

b, breadth of cotter $= 1.3d_1$;
t, thickness of cotter $= .3d_1$;
d, diameter of pierced rod $= 1.2d_1$;
D, diameter of socket in front of cotter $= 2.4d_1$ or $2d$.
D_1, diameter of socket behind cotter $= 2d_1$;
D_2, diameter of collar on rod $R = 1.5d_1$;
t, thickness of collar on rod $R = \frac{1}{2}d_1$;
l, the length of the rod and socket beyond the cotter = from $\frac{3}{4}d_1$ to d_1.

When d is known the diameter of the solid rod $(d_1) = .82d$. The clearance c may be made $\frac{1}{8}''$. The cotter need not extend beyond the greatest diameter of the socket more than $\frac{1}{2}''$ when driven home.

COTTER AND GIB.

When one of the pieces connected by the cotter is a thin strap, as in Fig. 340, a second cotter, called a gib, is used. The gib is provided with a head at the ends which project over the strap S, thus preventing it (the strap) from being forced open by the friction between it and the cotter as the latter is driven into place. Figs. 340 and 341 show the application of gib and cotter to strap-end connecting-rods, where *R* is the rod and *S* the strap. When two gibs are used, as in Fig. 342, the sliding surface on each side of the cotter is the same. Instead of having both gibs tapered, as shown in Fig. 342, one of them may be parallel and the taper all on one side of the cotter. The strength of the gib and cotter in combination is made the same as the single cotter and should be proportional to the strap *S*. The working strength of the strap at the thinnest part is found by the equation

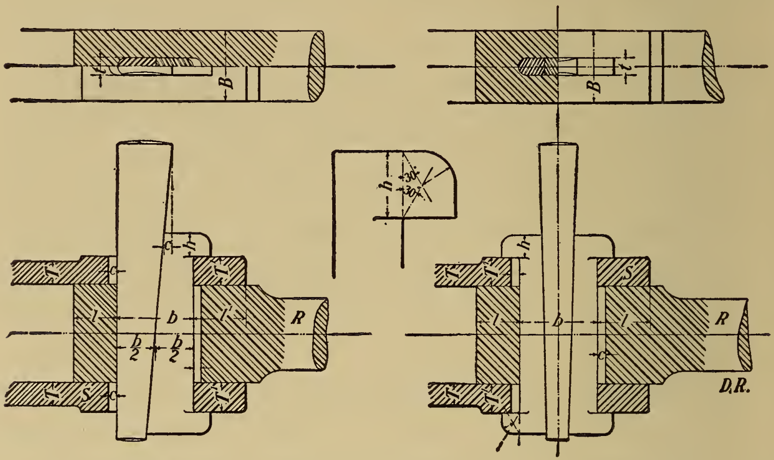


FIG. 340. FIG. 341. FIG. 342.

$$\left.\begin{aligned} 2BTf_t &= P. \\ \text{from which} \qquad T &= \frac{P}{2Bf_t} \end{aligned}\right\} \quad \ldots\ldots \quad (12)$$

where *P* is the maximum pull on the rod, *T* the thickness.

and B the breadth of the strap. Then as the gib and cotter are to have the same strength as the single cotter, and as B is equal to, or a little greater than d (the diameter of the rod), t may be made equal to $.25B$ and

$$b = 1.3\sqrt{\frac{2BT}{.7854}},$$

T', the thickness of the strap where it is pierced by the cotter, should not be less than $1.3T$. l', the distance from the gib to the end of the strap, $= 2T$. l, the distance from the cotter to the end of the rod, $= 1.5T$. c, the clearance, should not be less than c' (the difference between the widest part of the cotter and the width of the cotter at the top of the gib-head). The method of constructing gib-heads is shown in Fig. 341, where h, the height of the gib-head, $= 1\frac{1}{4}t$.

Nut Wrench.—Fig. 343 shows a common straight nut

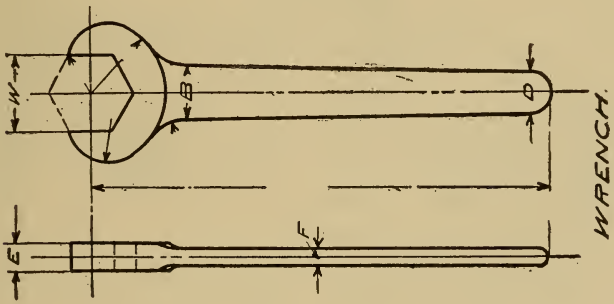


FIG. 343.

wrench. They are made of wrought iron or steel, drop forged. Table 9 gives the usual proportions.

TABLE 9.

PROPORTIONS FOR WRENCHES.

$B = W \times .8$ $D = W \times .65$

$E = W \times .4$ $F = W \times .25$

$L = W \times .7$

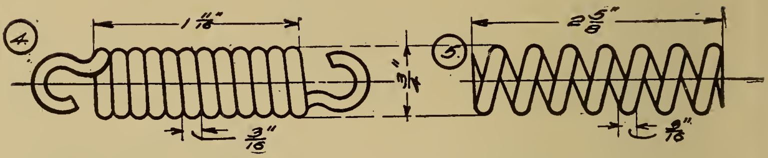


FIG. 344.

Helical Springs.—The following formulæ is given by Clarke, who quotes from a report on safety valves made by the Inst. of Engrs. and Shipbuilders of Scotland:

$$E = \frac{d^3 \times w}{D^4 \times C}, \quad D = \sqrt{\frac{wd}{3}}, \text{ for round steel,}$$

and

$$D = \sqrt{\frac{wd}{4.9}}, \text{ for square steel.}$$

E = compression or extension of one coil in inches;

d = diameter from center to center of steel bar of which the spring is made, in inches;

w = weight applied in pounds;

D = diameter, or side of the square of the steel bar, in sixteenths of an inch;

C = a constant, which may be taken as 22 for round steel and 30 for square steel.

To obtain the total deflection for a given spring, multiply the deflection for one coil by the number of free coils.

In Fig. 344, 4 is an example of a helical tension spring and 5 that of a compression spring.

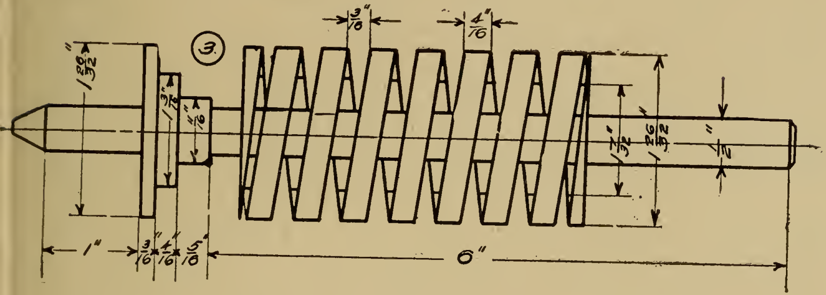

3.
3/16"
4/16"
1 29/32"
1 3/16"
4/16"
1"
3/16"
4/16"
5/16"
6"
1 7/32"
1 26/32
1/2"

FIG. 345.

Fig. 345 shows an example of a coil spring for a steam safety-valve with its spindle.

Cast-iron Flanges.—Figs. 346 and 347 show drawings of cast iron flanges of ordinary design. Their correct proportions are given in Table 10.

FLANGES.

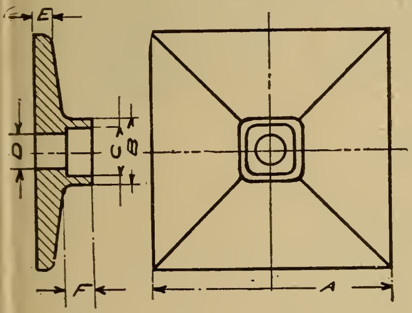


FIG. 346.

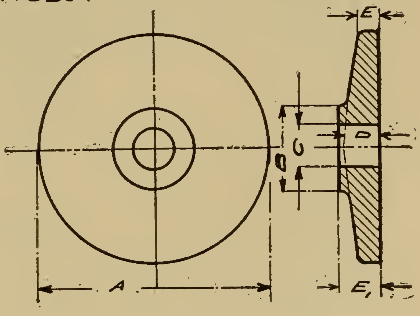


FIG. 347.

Chains.—Fig. 348 shows a drawing of a common end link and narrow shackle used for general purposes. Table 11 gives the United States Navy standard proportions.

TABLE 10.

PROPORTIONS FOR FLANGES.

Dia. of Bolt.	*A*	*B*	*C*	*D*	*E*	*F*	Dia. of Bolt.	*A*	*B*	*C*	*D*	*E*
"	"	"	"	"	"	"	"	"	"	"	"	"
1/2	6	1 3/8	1	9/16	1/2	3/4	1/4	1 5/8	5/8	5/16	1/4	3/16
3/4	7	1 5/8	1 3/8	13/16	5/8	7/8	1/2	3 1/4	1 1/4	5/8	7/16	5/16
1	8	2 3/8	1 3/4	1 1/8	3/4	1	3/4	4 7/8	1 3/4	7/8	3/4	7/16
1 1/4	10	2 3/4	2 1/8	1 3/8	3/4	1 1/8	1	6 1/2	2 1/4	1 1/8	1	1/2
2	12	4	3 1/4	2 1/8	7/8	1 5/8	1 3/8	9	3	1 1/2	1 1/4	9/16
2 1/4	15	5	4	2 5/8	1	2 1/8	1 5/8	10 1/2	3 1/2	1 3/4	1 3/8	3/4
3	18	6	4 3/4	3 1/8	1 1/8	2 3/8	2	13	4 1/4	2 1/8	1 5/8	1

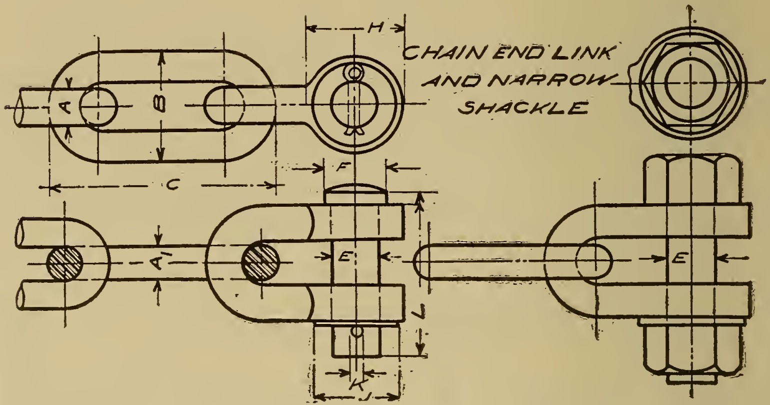


FIG. 348.

TABLE 11.

A	*A*₁	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*L*	*M*	*N*	*O*
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
1	1 1/8	3 3/4	6 5/8	4 5/8	1 1/2	2 1/16	3/8	3	2 3/4	1/4	4 7/8	5 3/8	5/8	3 7/8
1 1/8	1 1/4	4 1/8	7 1/2	5 1/8	1 3/4	2 5/16	7/16	3 1/4	3 1/4	5/16	5 1/2	6	3/4	4 1/2
1 1/4	1 3/8	4 9/16	8 1/8	5 3/4	1 7/8	2 7/16	7/16	3 3/4	3 1/2	5/16	6	6 5/8	3/4	4 3/4
1 1/2	1 5/8	5 3/8	9 5/8	6 7/8	2 1/4	3 1/16	9/16	4 1/2	4	3/8	7	7 3/4	7/8	5 1/2
1 3/4	1 7/8	6 1/4	11 3/8	8	2 3/4	3 11/16	11/16	5 1/2	5	7/16	8	9 1/8	1	6 3/8
1 7/8	2	6 11/16	11 3/4	8 1/2	2 3/4	3 11/16	11/16	5 1/2	5	7/16	8 1/2	9 5/8	1 1/8	6 3/4

Ball Crank Handle.—Fig. 349 shows a drawing of a form of handle used for ball cranks on machine tools. The dimensions are given below in Table 12.

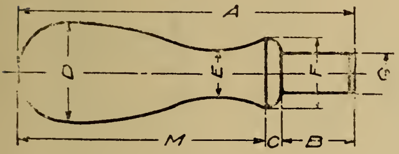


FIG. 349.

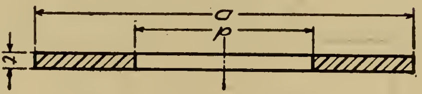


FIG. 350.

TABLE 12.

No.	*A*	*B*	*C*	*D*	*E*	*F*	*G*
0	2¼	½	3/32	11/16	11/32	½	5/16
1	2¾	5/8	1/8	13/16	11/32	5/8	3/8
2	3⅛	¾	1/8	1	½	5/8	3/8
3	3½	¾	5/32	1 1/16	17/32	¾	7/16
4	4	7/8	3/16	1⅛	9/16	27/32	7/16
5	4⅜	7/8	7/32	1 3/16	19/32	15/16	15/32

Washers.—Fig. 350 is a cross-section of the ordinary circular washer for all kinds of bolts. Table 13 gives the proportions for different diameters of bolts.

TABLE 13.

Diam. of Bolt.	*d*	*D*	U. S. Wire Gauge	Diam. of Bolt.	*d*	*D*	U. S. Wire Gauge
3/16	¼	9/16	No. 18	7/8	15/16	2¼	No. 9
¼	5/16	¾	No. 16	1	1 1/16	2½	No. 9
5/16	3/8	7/8	No. 16	1⅛	1¼	2¾	No. 9
3/8	7/16	1	No. 14	1¼	1⅜	3	No. 9
7/16	½	1¼	No. 14	1⅜	1½	3¼	No. 8
½	9/16	1⅜	No. 12	1½	1⅝	3½	No. 8
9/16	5/8	1½	No. 12	1⅝	1¾	3¾	No. 8
5/8	11/16	1¾	No. 10	1¾	1⅞	4	No. 8
¾	13/16	2	No. 10	2	2⅛	4½	No. 8

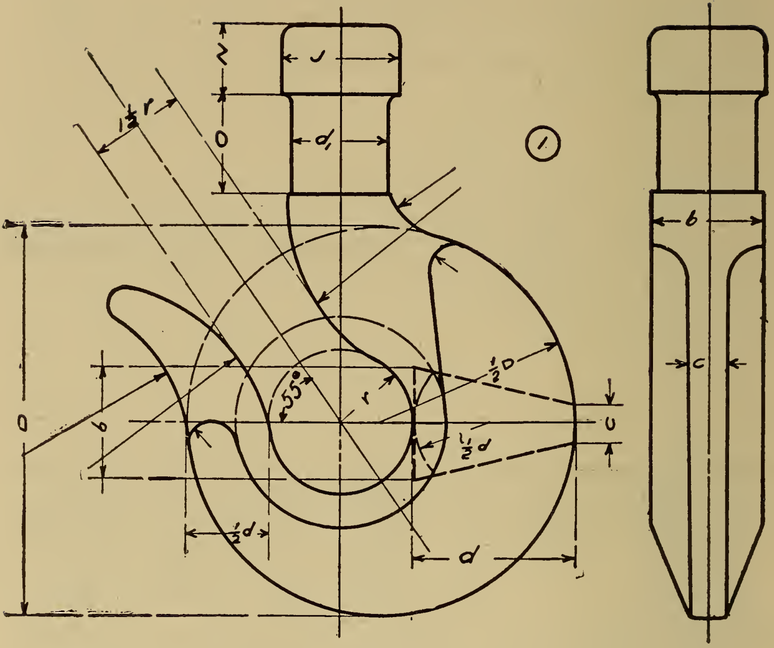

J
d_1
O
$1\frac{1}{2}r$
①
$\frac{1}{2}D$
55°
r
b
D
c
$\frac{1}{2}d$
$\frac{1}{2}d$
d
b
c

FIG. 351.

CRANE HOOKS.

Notation: *

P = load in pounds;

A = area in square inches;

R^2 = square of the radius of gyration;

f = allowable fiber strain in pounds per square inch.

$$f=\frac{P}{A}+\frac{Pxe_1}{I}=\frac{P}{A}+\frac{Pxe_1}{AR^2}.$$

$$\therefore\quad \frac{P}{f}=\frac{A}{1+\frac{xe_1}{R^2}}, \quad . \; . \; . \; . \qquad . \; . \; . \quad \text{(General Formula)}$$

---

* *American Machinist*, Oct. 31, 1901.

For section considered as a trapezoid

$$A=\frac{b+c}{2}\times d, \quad . \quad . \quad (1) \qquad R^2=\frac{d^2(b^2+4bc+c^2)}{18(b^2+2bc+c^2)}, \quad . \quad (2)$$

$$e_1=\frac{b+2c}{b+c}\times\frac{d}{3}, \quad . \quad . \quad (3) \qquad x=\left(\frac{b+2c}{b+c}\times\frac{d}{3}\right)+r, \quad . \quad (4)$$

Assuming $b=.656d$; $c=.22d$. Then

$$\frac{P}{f}=\frac{d^3}{7.79d+11.113r}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$D=2r+1\tfrac{1}{2}d, \qquad d_1=0.5d.$$

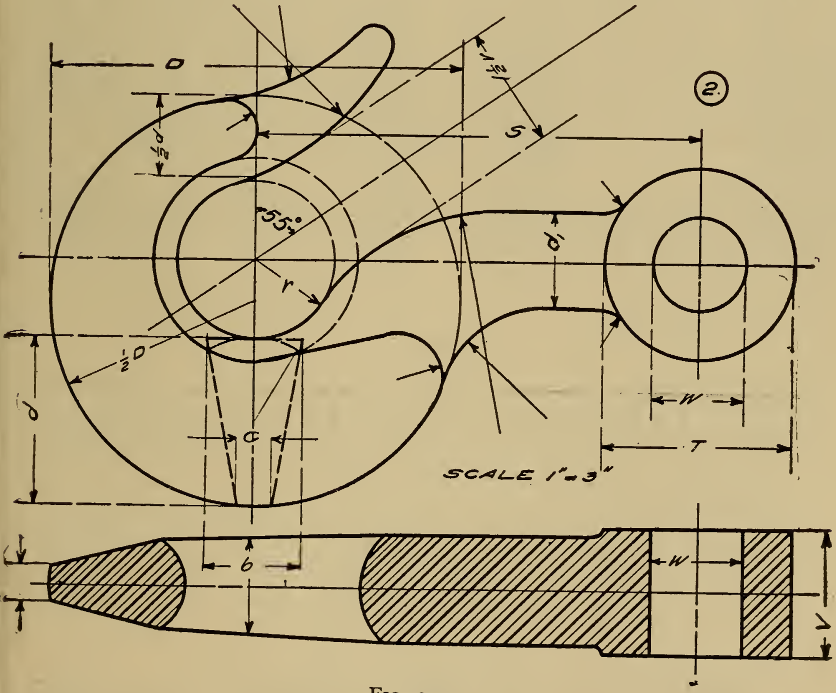


FIG. 352.

P and f being known, assume r to suit. Divide P by f and find the quotient in the column headed by the required r, in

Table 14. At the side of the table in the same row will be found the necessary depth of section *d*.

TABLE 14.

d	*r*										
	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
2.00	.378	.335	.300	.271	.248	.228	.212	.197	.184	.173	.164
2.25	.493	.440	.397	.362	.333	.308	.286	.267	.251	.237	.224
2.50	.624	.562	.511	.468	.432	.401	.375	.352	.330	.312	.296
2.75	.771	.698	.639	.589	.546	.509	.477	.448	.423	.400	.380
3.00	.934	.851	.783	.725	.675	.631	.592	.558	.528	.501	.477
3.25	1.112	1.019	.941	.875	.818	.767	.722	.682	.646	.614	.585
3.50	1.306	1.204	1.117	1.042	.975	.918	.867	.820	.778	.742	.707
3.75	1.517	1.404	1.307	1.223	1.140	1.084	1.025	.973	.926	.882	.843
4.00	1.743	1.620	1.514	1.421	1.338	1.265	1.199	1.139	1.086	1.037	.993

In Table 15 the proper proportions for the given loads have been worked out.

TABLE 15.

Tons	Lbs.	*r*	*d*	*D*	*b*	*c*	d_1	*j*	*O*	*N*	*S*	*T*	*W*	*V*
$\frac{1}{2}$	1000	1	2	5	$1\frac{5}{16}$	$\frac{7}{16}$	1	$1\frac{1}{4}$	1	$\frac{3}{4}$	5	$1\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{4}$
1	2000	1	$2\frac{1}{4}$	$5\frac{5}{16}$	$1\frac{13}{32}$	$\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$\frac{13}{16}$	7	$2\frac{3}{8}$	$1\frac{3}{16}$	$1\frac{3}{4}$
2	4000	$1\frac{1}{4}$	3	7	2	$\frac{5}{8}$	2	2	$1\frac{3}{4}$	$1\frac{1}{8}$	9	$3\frac{1}{2}$	$1\frac{3}{4}$	2
$2\frac{1}{2}$	5000	$1\frac{1}{2}$	$3\frac{1}{2}$	$8\frac{1}{4}$	$2\frac{5}{16}$	$\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	2	$1\frac{7}{16}$	10	4	2	$2\frac{1}{2}$
5	10000	$2\frac{1}{2}$	$5\frac{1}{4}$	$12\frac{7}{8}$	3	$1\frac{5}{32}$	$2\frac{3}{4}$	3	$2\frac{1}{2}$	$1\frac{1}{2}$	14	6	$2\frac{3}{4}$	$4\frac{3}{4}$
10	20000	4	$7\frac{1}{2}$	$19\frac{1}{4}$	5	$1\frac{21}{32}$	4	$4\frac{3}{8}$	4	2	15	7	$3\frac{1}{2}$	6

Hand Wheel.—Fig. 353 shows a drawing of a standard hand wheel used for globe valves, etc., and in Table 16 is given the usual proportions.

TABLE 16.

Dia.	*A*	*B*	*b*	*d*	*T*	*t*	*L*
4	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{16}$	1	$\frac{1}{4}$	$\frac{7}{32}$	$\frac{3}{4}$
5	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{16}$	$1\frac{1}{8}$	$\frac{9}{32}$	$\frac{7}{32}$	$\frac{13}{16}$
6	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{15}{16}$
7	$\frac{11}{64}$	$\frac{11}{64}$	$\frac{9}{16}$	$1\frac{3}{8}$	$\frac{11}{32}$	$\frac{9}{32}$	1
8	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{5}{8}$	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$1\frac{1}{8}$
9	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{11}{16}$	$1\frac{5}{8}$	$\frac{13}{32}$	$\frac{11}{32}$	$1\frac{1}{4}$
10	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$1\frac{3}{4}$	$\frac{7}{16}$	$\frac{3}{8}$	$1\frac{5}{16}$
11	$\frac{15}{16}$	$\frac{15}{16}$	$\frac{3}{4}$	$1\frac{7}{8}$	$\frac{15}{32}$	$\frac{3}{8}$	$1\frac{3}{8}$
12	1	1	$\frac{13}{16}$	2	$\frac{1}{2}$	$\frac{13}{32}$	$1\frac{1}{2}$

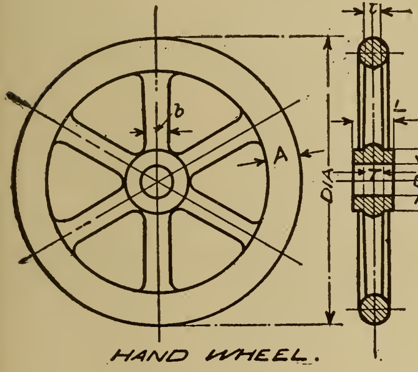


FIG. 353.

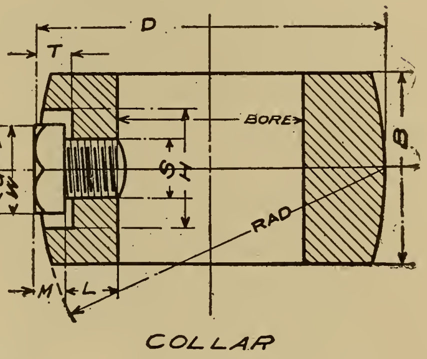


FIG. 354.

Shaft Collars.—Fig. 354 shows a usual design for shaft collars made in cast iron. Table 17 gives the correct proportions.

TABLE 17.

Bore.	*B*	*D*	*H*	*L*	*M*	*S*	*T*	*W*
$1\frac{7}{16}$	$1\frac{5}{8}$	$2\frac{3}{4}$	$\frac{7}{8}$	$\frac{17}{32}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{5}{8}$
$1\frac{11}{16}$	$1\frac{7}{8}$	$3\frac{1}{4}$	1	$\frac{19}{32}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{3}{4}$
$2\frac{3}{16}$	$2\frac{1}{8}$	4	$1\frac{1}{4}$	$\frac{21}{32}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{15}{16}$
$2\frac{11}{16}$	$2\frac{1}{2}$	$4\frac{3}{4}$	$1\frac{1}{2}$	$\frac{23}{32}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{7}{16}$	$1\frac{1}{8}$
$3\frac{3}{16}$	$2\frac{3}{4}$	$5\frac{3}{4}$	$1\frac{1}{2}$	1	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{7}{16}$	$1\frac{1}{8}$
$3\frac{11}{16}$	3	$6\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{16}$	$\frac{1}{16}$	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{5}{16}$
$4\frac{3}{16}$	$3\frac{1}{4}$	$7\frac{3}{4}$	2	$1\frac{7}{16}$	$\frac{1}{2}$	1	$\frac{9}{16}$	$1\frac{1}{2}$
$4\frac{15}{16}$	$3\frac{5}{8}$	$8\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{8}$	$\frac{9}{16}$	$1\frac{5}{8}$
$5\frac{7}{16}$	$3\frac{7}{8}$	$9\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{8}$	$\frac{9}{16}$	$1\frac{5}{8}$

Frictional Coupling.—Fig. 354 shows three views of Butler's frictional coupling. It is somewhat like the Sellers coupling, except that it has neither bolts nor keys, the conical bushes being held in position by round nuts threaded into the muff. The conical bushes are split at the side, and when they are in position on the shaft the split sides are at right angles to each other; this arrangement allows a key-driver to be introduced through one of these openings (after the nuts have been removed) to drive out the other bush when it is desired to remove the coupling from the shaft. The bushes are guided into position by small dowel-pins which enter short grooves provided for them inside the muff. The $\frac{1}{2}''$ round holes shown in top and bottom at the centre of the muff are used to see when the ends of the shafts come together, for then only will the coupling be in its proper position.

The threads on the lock-nuts should be that number per inch used on a pipe whose *outside* diameter is nearest to the outside diameter of the nut. The lock-nuts are screwed into position by means of a spanner wrench having projecting pieces which fit into the recesses shown in end elevation. The taper of the conical bushes may be made $\frac{3}{4}''$ in $12''$ *on the diameter*. The faces marked with small f are to be finished.

The principal proportions of this coupling are as follows:

d = diameter of shaft;
D = diameter of muff = $2.25d$;
L = length of muff = $4d$.

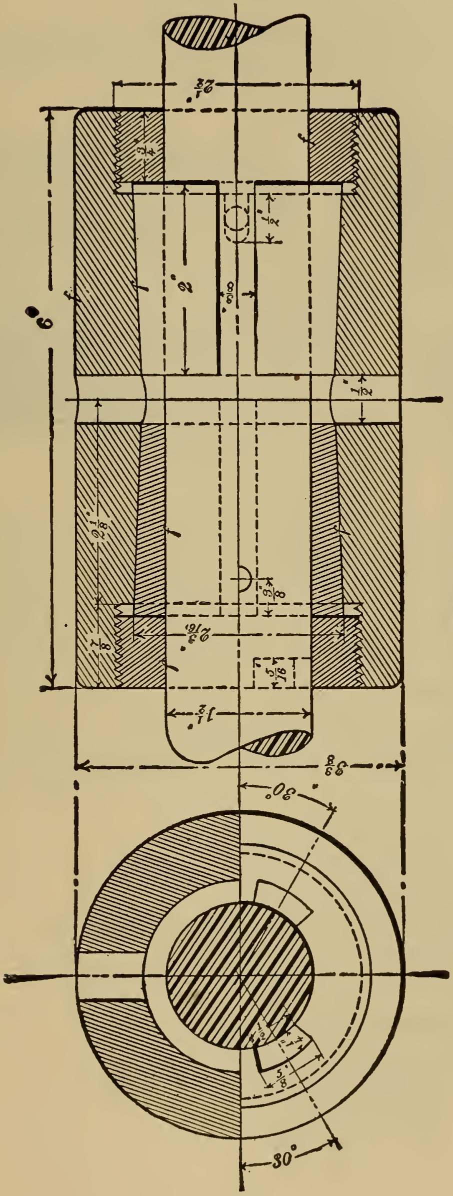

2 1/4"
3/4
f
1/2"
2"
3/8"
6"
1/2"
2 1/8
3/8
7/8
2 3/16"
5/16
1 1/2"
3 3/8
30°
1
5/8
30°

Fig. 355.

Stuart's Clamp Coupling.—This coupling, shown in Fig. 355, differs from the Sellers coupling in having tapered wedges instead of conical sleeves; these tapered wedges and opposite halves of each end of the muff are bored to the size of the shaft. Studs and nuts hold the wedges in place, making, on the whole, a cheap and effective coupling without the use of keys.

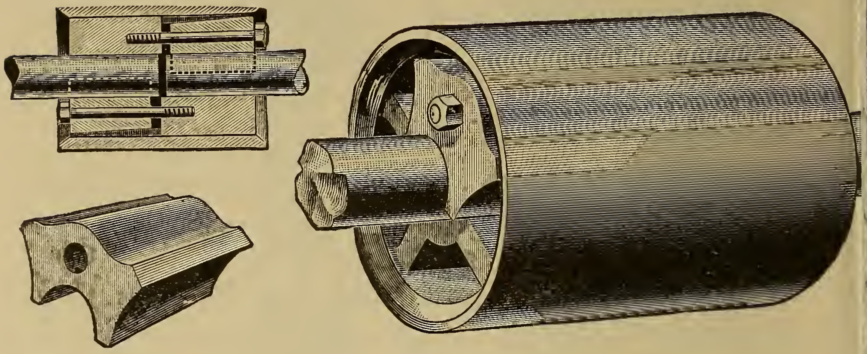


FIG. 356.

The principal dimensions of this coupling for various diameters of shaft are given in the following proportions:

Let d = diameter of shaft;
D = diameter of muff;
L = length of muff.

Then for shafts from $1\frac{1}{4}''$ to $2\frac{3}{4}''$ diameter

$$D = 3.25d, \qquad L = 4.25d;$$

for shafts from $2\frac{3}{4}''$ up

$$D = 3d, \qquad L = 4d.$$

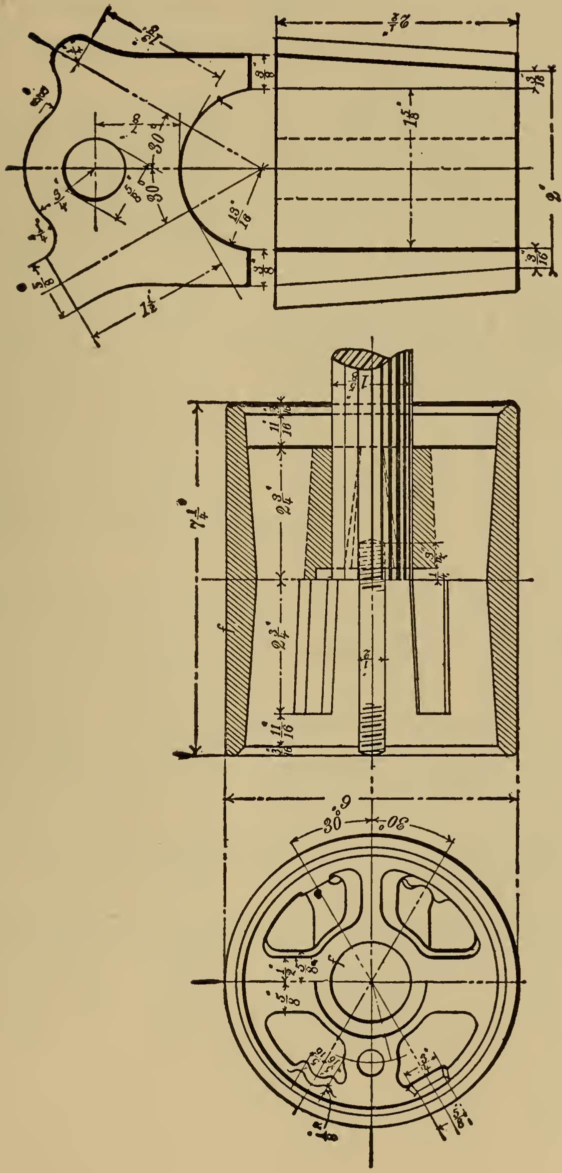

2 3/4"
15/8"
2"
3/8"
3/16"
13/16
1 1/2"
5/8
30°
7 1/4"
11/16
1/2
9"
f

FIG. 357.

Connecting-rods.—In steam and other engines the connecting-rod connects the rotating crank with the reciprocating cross-head.

There are many styles of connecting-rods, and various methods are employed for taking up the wear of the brasses. Figs. 356 and 357 show good examples of rods used in stationary, locomotive, and marine engines of the most modern types.

Fig. 358 is the rod used by the Buckeye Engine Co. for their "Tangye" type of engine. The crank end is *solid*, the brasses are lined with babbitt, and adjustment for wear is had by means of a tapered steel block and screws. The cross-head end is called a *strap* end. The strap is firmly bound to the end of the rod with a cotter-key and gib, which also controls the adjustment for wear.

Fig. 359 has strap ends front and back. Keys are inserted between the straps and the rod to prevent the shear of the strap-bolts. The construction of this rod and the method employed to take up the wear are plainly shown in the figure. The Erie City Iron Works use this rod on their stationary engines.

Exercise 132.—Make the drawings as shown in Fig. 358. (*Scale 6" = 1 foot.*)

Exercise 133.—Make the drawings as shown in Fig. 359.

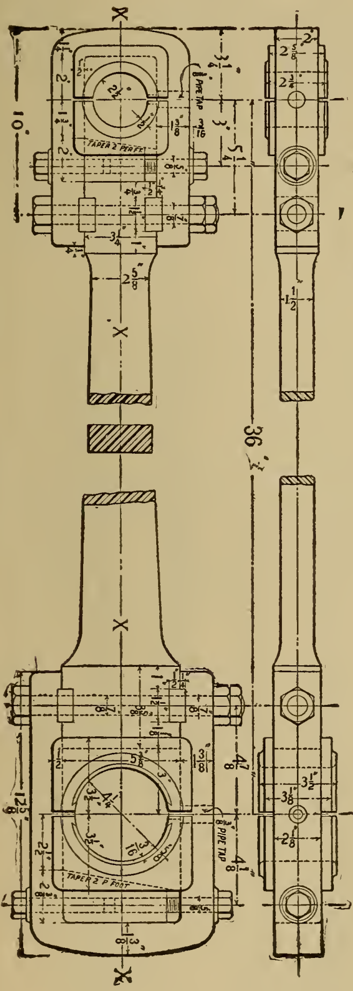

X
10"
TAPER 2 PER FT.
PIPE TAP
36'
TAPER 2 P FOOT
PIPE TAP

FIG. 359.

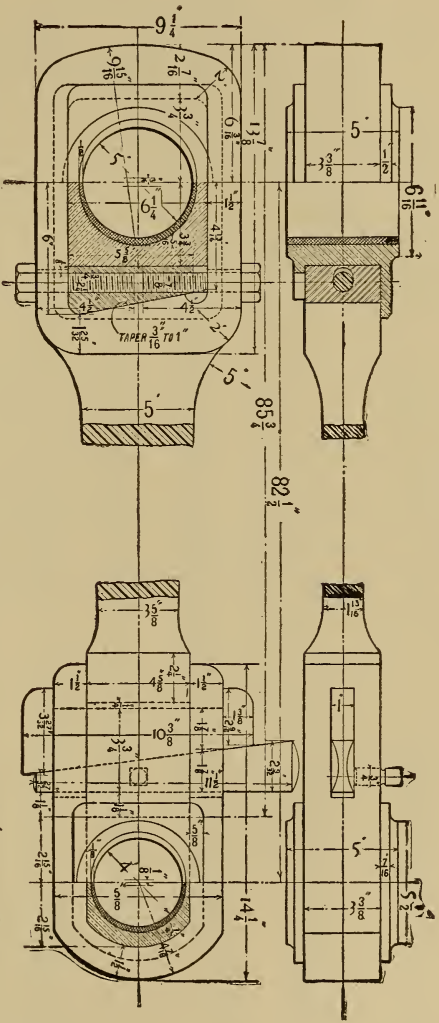

9¼"
5"
6¼
TAPER 3/16" TO 1"
5"
85¾
82½"
10⅜"
14¼"
5"

FIG. 358.

TABLE 18.

WIRE AND SHEET-METAL GAUGES COMPARED.

Number of Gauge.	Birmingham (or Stubs' Iron) Wire Gauge.	American or Brown and Sharpe Gauge.	Roebling's and Washburn & Moen's Gauge.	Stubs' Steel Wire Gauge. (See also p. 29.)	British Imperial Standard Wire Gauge. (Legal Standard in Great Britain since March 1, 1884.)		U. S. Standard Gauge for Sheet and Plate Iron and Steel. (Legal Standard since July 1, 1893.)	Number of Gauge.
	inch.	inch.	inch.	inch.	inch.	millim.	inch.	
0000000			.49		.500	12.7	.5	7/0
000000			.46		.464	11.78	.469	6/0
00000			.43		.432	10.97	.438	5/0
0000	.454	.46	.393		.4	10.16	.406	4/0
000	.425	.40964	.362		.372	9.45	.375	3/0
00	.38	.3648	.331		.348	8.84	.344	2/0
0	.34	.32486	.307		.324	8.23	.313	0
1	.3	.2893	.283	.227	.3	7.62	.281	1
2	.284	.25763	.263	.219	.276	7.01	.266	2
3	259	.22942	.244	.212	.252	6.4	.25	3
4	.238	.20431	.225	.207	.232	5.89	.234	4
5	.22	.18194	.207	.204	.212	5.38	.219	5
6	.203	.16202	.192	.201	.192	4.88	.203	6
7	.18	.14428	.177	.199	.176	4.47	.188	7
8	.165	.12849	.162	.197	.16	4.06	.172	8
9	.148	.11443	.148	.194	.144	3.66	.156	9
10	.134	.10189	.135	.191	.128	3.25	.141	10
11	.12	.09074	.12	.188	.116	2.95	.125	11
12	.109	.08081	.105	.185	.104	2.64	.109	12
13	095	.07196	.092	.182	.092	2.34	.094	13
14	.083	.06408	.08	.180	.08	2.03	.078	14
15	.072	.05707	.072	.178	.072	1.83	.07	15
16	.065	.05082	.063	.175	.064	1.63	.0625	16
17	.058	04526	.054	.172	.056	1.42	.0563	17
18	.049	0403	.047	.168	.048	1.22	.05	18
19	.042	.03589	.041	.164	.04	1.02	.0438	19
20	.035	.03196	.035	.161	.036	.91	.0375	20
21	.032	02846	.032	.157	.032	.81	.0344	21
22	.028	.02535	.028	.155	.028	.71	.0313	22
23	.025	.02257	.025	.153	.024	.61	.0281	23
24	.022	.0201	.023	.151	.022	.56	.025	24
25	.02	.0179	.02	.148	.02	.51	.0219	25
26	.018	.01594	.018	.146	.018	.46	.0188	26
27	.016	.01419	.017	.143	.0164	.42	.0172	27
28	.014	.01264	.016	.139	.0148	.38	.0156	28
29	.013	.01126	.015	.134	.0136	.35	.0141	29
30	.012	.01002	.014	.127	.0124	.31	.0125	30
31	.01	.00893	.0135	.120	.0116	.29	.0109	31
32	.009	.00795	.013	.115	.0108	.27	.0101	32
33	.008	.00708	.011	.112	.01	.25	.0094	33
34	.007	0063	.01	.110	.0092	.23	.0086	34
35	.005	.00561	.0095	.108	.0084	.21	.0078	35
36	004	.005	.009	.106	.0076	.19	.007	36
37		.00445	.0085	.103	.0068	.17	.0066	37
38		.00396	.008	.101	.006	.15	.0063	38
39		.00353	.0075	.099	.0052	.13		39
40		.00314	.007	.097	.0048	.12		40
41				.095	.0044	.11		41
42				.092	.004	.10		42
43				.088	.0036	.09		43
44				.085	.0032	.08		44
45				.081	.0028	.07		45
46				.079	.0024	.06		46
47				.077	.002	.05		47
48				.075	.0016	.04		48
49				.072	.0012	.03		49
50				.069	.001	.025		50

TABLE 19.

DIFFERENT COLORS OF IRON CAUSED BY HEAT. (Pouillet.)

Cent.	Fahr.	Color.
210°	410°	Pale yellow.
221	430	Dull yellow.
256	493	Crimson.
261	502	Violet, purple, and dull blue; between 261° C. and 370° C. it passes to bright blue, to sea-green, and then disappears.
370	680	
500	932	Commences to be covered with a light coating of oxide; loses a good deal of its hardness, becomes much more impressible to the hammer, and can be twisted with ease.
525	977	Becomes nascent red.
700	1292	Sombre red.
800	1472	Nascent cherry.
900	1657	Cherry.
1000	1832	Bright cherry.
1100	2012	Dull orange.
1200	2192	Bright orange.
1300	2372	White.
1400	2552	Brilliant white—welding **heat.**
1500	2732	Dazzling white.
1600	2912	

TABLE 20.

TABLE OF DECIMAL EQUIVALENTS OF ONE INCH.

1/64	.015625	17/64	.265625	33/64	.515625	49/64	.765625
1/32	.03125	9/32	.28125	17/32	.53125	25/32	.78125
3/64	.046875	19/64	.296875	35/64	.546875	51/64	.796875
1/16	.0625	**5/16**	.3125	**9/16**	.5625	**13/16**	.8125
5/64	.078125	21/64	.328125	37/64	.578125	53/64	.828125
3/32	.09375	11/32	.34375	19/32	.59375	27/32	.84375
7/64	.109375	23/64	.359375	39/64	.609375	55/64	.859375
1/8	.125	**3/8**	.375	**5/8**	.625	**7/8**	.875
9/64	.140625	25/64	.390625	41/64	.640625	57/64	.890625
5/32	.15625	13/32	.40625	21/32	.65625	29/32	.90625
11/64	.171875	27/64	.421875	43/64	.671875	59/64	.921875
3/16	.1875	**7/16**	.4375	**11/16**	.6875	**15/16**	.9375
13/64	.203125	29/64	.453125	45/64	.703125	61/64	.953125
7/32	.21875	15/32	.46875	23/32	.71875	31/32	.96875
15/64	.234375	31/64	.484375	47/64	.734375	63/64	.984375
1/4	.25	**1/2**	.50	**3/4**	.75	**1**	

TABLE 21.

CIRCUMFERNCES AND AREAS OF CIRCLES ADVANCING BY EIGHTHS.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
1/64	.04909	.00019	2 11/16	8.4430	5.6727	6 5/8	20 813	34.472
1/32	.09818	.00077	3/4	8.6394	5.9396	3/4	21.206	35.785
3/64	.14726	.00173	13/16	8.8357	6.2126	7/8	21.598	37.122
1/16	.19635	.00307	7/8	9.0321	6.4918			
3/32	.29452	.00690	15/16	9.2284	6.7771	7	21.991	38.485
1/8	.39270	.01227				1/8	22.384	39.871
5/32	.49087	.01917	3	9.4248	7.0686	1/4	22.776	41.282
3/16	.58905	.02761	1/16	9.6211	7.3662	3/8	23.169	42.718
7/32	.68722	.03758	1/8	9.8175	7.6699	1/2	23.562	44.179
1/4	.78540	.04909	3/16	10.014	7.9798	5/8	23.955	45.664
9/32	.88357	.06213	1/4	10.210	8.2958	3/4	24.347	47.173
5/16	.98175	.07670	5/16	10.407	8.6179	7/8	24.740	48.707
11/32	1.0799	.09281	3/8	10.603	8.9462			
3/8	1.1781	.11045	7/16	10 799	9.2806	8	25.133	50.265
13/32	1.2763	.12962	1/2	10.996	9.6211	1/8	25.525	51.849
7/16	1.3744	.15033	9/16	11.192	9.9678	1/4	25.918	53.456
15/32	1.4726	.17257	5/8	11.388	10.321	3/8	26.311	55.088
1/2	1.5708	.19635	11/16	11.585	10.680	1/2	26.704	56.745
17/32	1.6690	.22166	3/4	11.781	11.045	5/8	27.096	58.426
9/16	1.7671	.24850	13/16	11.977	11.416	3/4	27.489	60.132
19/32	1.8653	.27688	7/8	12.174	11.793	7/8	27.882	61.862
5/8	1.9635	.30680	15/16	12.370	12.177			
21/32	2.0617	.33824				9	28.274	63.617
11/16	2.1598	.37122	4	12.566	12.566	1/8	28.667	65.307
23/32	2.2580	.40574	1/16	12.763	12.962	1/4	29.060	67.201
3/4	2.3562	.44179	1/8	12.959	13.364	3/8	29.452	69.029
25/32	2.4544	.47937	3/16	13.155	13.772	1/2	29.845	70.882
13/16	2.5525	.51849	1/4	13.352	14.186	5/8	30.238	72.760
27/32	2.6507	.55914	5/16	13.548	14.607	3/4	30.631	74.662
7/8	2.7489	.60132	3/8	13.744	15.033	7/8	31.023	76.589
29/32	2.8471	.64504	7/16	13.941	15.466			
15/16	2.9452	.69029	1/2	14.137	15.904	10	31.416	78.540
31/32	3.0434	.73708	9/16	14.334	16.349	1/8	31.809	80.516
			5/8	14.530	16.800	1/4	32.201	82.516
1	3.1416	.7854	11/16	14 726	17.257	3/8	32.594	84.541
1/16	3.3379	.8866	3/4	14.923	17.721	1/2	32.987	86.590
1/8	3.5343	.9940	13/16	15.119	18.190	5/8	33.379	88.664
3/16	3.7306	1.1075	7/8	15.315	18.665	3/4	33.772	90.763
1/4	3.9270	1.2272	15/16	15.512	19.147	7/8	34.165	92.886
5/16	4.1233	1.3530						
3/8	4.3197	1.4849	5	15.708	19.635	11	34.558	95.033
7/16	4.5160	1.6230	1/16	15.904	20.129	1/8	34.950	97.205
1/2	4.7124	1.7671	1/8	16.101	20.629	1/4	35.343	99.402
9/16	4.9087	1.9175	3/16	16.297	21.135	3/8	35.736	101.62
5/8	5.1051	2.0739	1/4	16.493	21.648	1/2	36.128	103.87
11/16	5.3014	2.2365	5/16	16.690	22.166	5/8	36.521	106.14
3/4	5.4978	2.4053	3/8	16.886	22.691	3/4	36.914	108.43
13/16	5.6941	2.5802	7/16	17.082	23.221	7/8	37.306	110.75
7/8	5.8905	2.7612	1/2	17.279	23.758			
15/16	6.0868	2.9483	9/16	17.475	24.301	12	37.699	113.10
			5/8	17.671	24.850	1/8	38.092	115.47
2	6.2832	3.1416	11/16	17.868	25.406	1/4	38.485	117.86
1/16	6.4795	3.3410	3/4	18.064	25.967	3/8	38.877	120.28
1/8	6.6759	3.5466	13/16	18.261	26.535	1/2	39.270	122.72
3/16	6.8722	3.7583	7/8	18.457	27.109	5/8	39.663	125.19
1/4	7.0686	3.9761	15/16	18.653	27.688	3/4	40.055	127.68
5/16	7.2649	4.2000				7/8	40.449	130.19
3/8	7.4613	4.4301	6	18.850	82.274			
7/16	7.6576	4.4664	1/8	19.242	g9.465			
1/2	7.8540	4.9087	1/4	19.635	30.680			
9/16	8.0503	5.1572	3/8	20.028	31.919			
5/8	8.2467	5.4119	1/2	20.420	33.183			

To find the weight of castings by the weight of pine patterns, multiply the weight of the pattern by 12 for cast iron, 13 for brass, 19 for lead, 12.2 for tin, 14.4 for zinc, and the product is the weight of the casting.

COURSE II.

PROBLEMS IN ADVANCED MECHANICAL DRAWING

INCLUDING

ISOMETRICAL DRAWING, ARCHITECTURAL DRAWING, SHEET METAL DRAFTING, MACHINE DETAILS, FREEHAND SKETCHING OF SMALL MACHINE PARTS AND WORKING DRAWINGS OF SAME.

COURSE II.

ADVANCED MECHANICAL DRAWING.

MINIMUM NUMBER OF PLATES AND MAXIMUM NUMBER OF HOURS ALLOWED TO COMPLETE EACH DIVISION OF THE WORK.

FIRST SEMESTER. SIX HOURS PER WEEK.

PLATE 22. Isometrical Drawing, to be handed in Sept. 24, 1909. (14 hours.)

PLATES 23 to 26 inclusive, Architectural Drawing, to be handed in November 12, 1909. (42 hours.)

PLATES 27 to 29 inclusive, Sheet Metal Drafting, to be handed in December 17, 1909. (30 hours.)

SECOND SEMESTER. SIX HOURS PER WEEK.

PLATE 30. Sheet Metal Drafting, to be handed in January 14, 1910. (12 hours.)

PLATES 31 to 33 inclusive, Machine Details, to be handed in March 11, 1910. (42 hours.)

PLATES 34 and 35, Freehand Sketches of small Machine parts and Working drawings of same. (60 hours.)

Total, 200 hours.

Isometrical Drawing.

Plate 22. Make freehand sketches of (1) Library Book Transferring Shelves (2) Drafting Table, and (3) a twelve drawer section of Drafting Room Lockers. These sketches are to be made on an isometric paper pad with dimensions and title. When sketches have been approved and signed, a finished pencil working drawing is to be made.

Architectural Drawing.

Plate 23. Make finished pencil drawing of framing joints as shown in Figs. 220–233 on Whatman's cold pressed white paper. When approved and signed this plate is to be inked and tinted in water colors.

Plate 24. Make finished pencil drawing of brick and stone work shown in Figs. 234–240 on cream detail paper. When pencil drawing has been approved and signed, it is to be traced on cloth and blue printed.

Plate 26. Make finished pencil drawing of the examples of Tuscan and Doric Orders of Architecture as shown in Figs. 243 and 244 on Whatman's cold pressed white paper. When pencil drawing is approved and signed, it is to be inked and the shaded and sectioned parts are to be tinted with a light wash of India ink.

Plate 28. Make finished pencil drawing of the example of the Ionic Order of Architecture as shown in Figs. 247 and 248 on Whatman's cold pressed white paper. When the pencil drawing is approved and signed, it is to be inked and the sectioned parts are to be tinted with a light wash of India ink.

PLATE 25. Make drawing of the Classic Renaissance Letters, Figs. 241 and 242. One alphabet 1″ high and alphabets of lesser height to fill one plate. Directions to be given by Instructor. This plate may be made at odd hours during the semester.

Sheet Metal Pattern Drawing.

PLATE 29. Make pattern drawings of objects as shown in Figs. 276 to 288 inclusive, according to directions given on page 216.

PLATE 30. Make pattern drawings of objects shown in Figs. 289 to 296 inclusive, according to directions given on page 218.

PLATE 31. Make pattern drawings of articles shown in Figs. 297 to 310 inclusive, according to directions given in pages 223 to 225.

PLATE 32. Draw the developments of pipe elbows as given in Figs. 311 to 314 according to directions given on page 226.

Machine Drawing.

PLATE 33.

PROB. 1. Draw the U. S. standard or Sellers' V-threads, Fig. 360, suitable for a screw 6″ in diameter. Scale three times full size.

See Table 1 for the value of p, the pitch of the screw. d is the nominal diameter of the screw, d_1 the effective diameter of the bolt, and n the number of threads per inch.

PROB. 2. Draw $2\frac{1}{2}$ threads of the "Whitworth," or English standard V-thread, Fig. 361, for 6″ screw. Scale three times full size.

PROB. 3. Draw the sectional outline of the square, knuckle and buttress shown in Figs. 362 and 363, respectively. $p = \frac{7}{8}''$. Scale, full size.

PROB. 4. Draw the section of a pipe screw, Fig. 364, for a wrought iron pipe 8″ in diameter. Scale, three times full size. See Table 2 for the number of threads per inch, the taper of the screw and the thickness, t, of the pipe.

PROB. 5. Make drawings of the screw thread conventions shown in Fig. 365. Scale, full size.

(1) is a right-hand double V-thread U. S. standard $d = 1''$.
(2) is a right-hand single V-thread U. S. standard $d = 1''$.
(3) is a right-hand single square thread U. S. standard $d = 1''$.
(4) is left-hand single V-thread U. S. standard $d = 1''$.
(5) is a right-hand double square thread U. S. standard $d = 1''$.
(6) is a right-hand single V-thread U. S. standard $d = \frac{3}{4}''$.

In the double thread the screw advances two pitches in each revolution, therefore the inclination of the thread is equal to the pitch. (6) is the standard convention used to represent threads on the common sizes of bolts and nuts.

PROB. 6. Draw the projections of a hexagonal nut, Fig. 366, for a bolt whose diameter d is equal to 1″. Scale, full size. $F = 1\frac{1}{2}d + \frac{1}{8}''$. $D = F \times 1.155$. $H = d$.

Construct the plan first. Draw the chamfer circle F and circumscribe a hexagon about it with the 30°×60° triangle and T-square. Project elevation and end elevation from the plan.

PROB. 7. Draw the projections of a square nut, Fig. 367, for a 1″ bolt. Scale, full size.

As in the last problem draw the plan first and project the

PLATE 33.

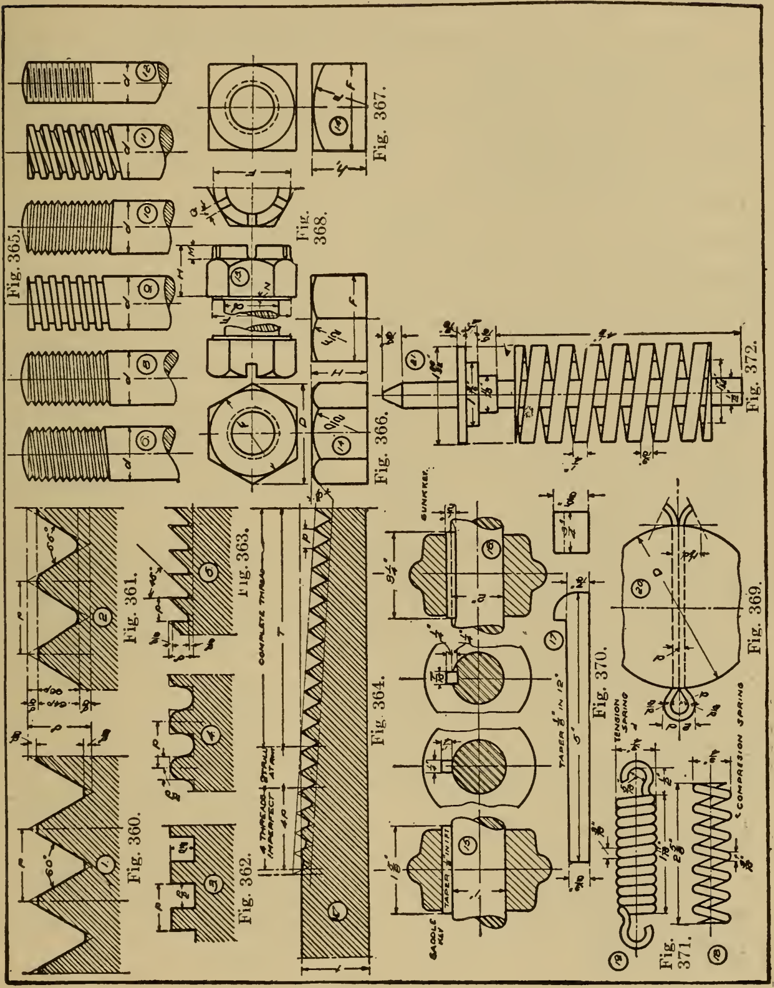


Fig. 360.
Fig. 361.
Fig. 362.
Fig. 363.
Fig. 364.
Fig. 365.
Fig. 366.
Fig. 367.
Fig. 368.
Fig. 369.
Fig. 370.
Fig. 371.
Fig. 372.
60°
COMPLETE THREAD
4 THREADS IMPERFECT
SUNK KEY
SADDLE KEY
TAPER 1/8" IN 12"
TENSION SPRING
COMPRESSION SPRING

elevations from it. A square nut should never be shown in elevation across the corners.

PROB. 8. Make drawings for 1″ bolt with castle nut, Fig. 368. Scale, full size.

The values of the letters in the figure are to be taken from Table 3 which gives the standard proportions adopted by the American Licensed Automobile Manufacturers. Use the same proportions for drawing the chamfer curves on the elevations as given for the U. S. standard nut. Make the saw cut in the head $.2d$ in width and the depth equal to $1\frac{1}{2}$ times the width.

PROB. 9. Make drawings of the rectangular keys and their connections shown in Fig. 370. Diameter of shaft D in No. 15 is equal to 1″. Scale, full size. Diameter of shaft in No. 16 is equal to 2″. Scale, 6″ = 1 foot. Take the key dimensions from Tables 5 and 6.

PROB. 10. Make drawings of the tension and compression springs shown in Figs. 371 and 372. Scale, full size.

Fig. 372 is a compression spring and spindle for a boiler safety valve. See model in drafting room.

PROB. 11. Make drawing of split pin shown in Fig. 369. Scale, full size. Assume $D = 3''$, and $d = .05D + .13$.

The split pin is made from half round wire which when pressed into form gives a circular cross-section.

Selections from the following problems may be made to conveniently fill the space in Plate 34, allowing for title and bill of material.

PLATE 34.

PROB. 1. Make drawing for a $2\frac{1}{2}$-ton crane-hook, Fig. 379. Scale, 6″ = 1 foot. Find values for the different letters in Table 15.

PLATE 34.

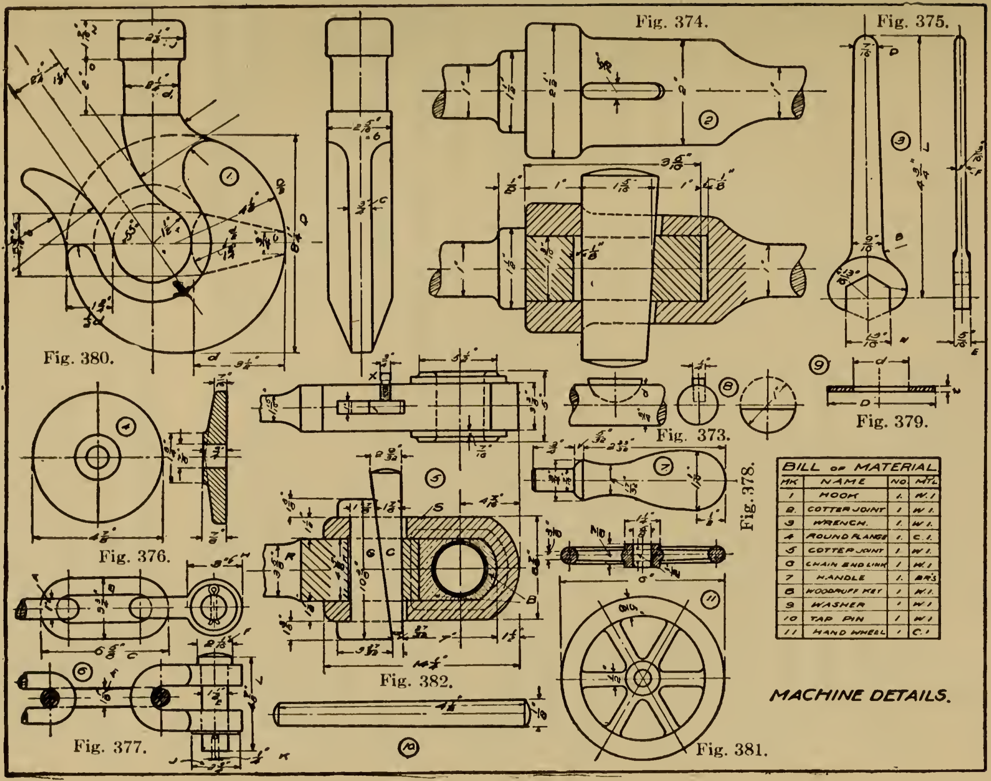


Fig. 373. Fig. 374. Fig. 375. Fig. 376. Fig. 377. Fig. 378. Fig. 379. Fig. 380. Fig. 381. Fig. 382.

BILL OF MATERIAL

MK	NAME	NO.	MTL
1	HOOK	1.	W.I
2.	COTTER JOINT	1	W.I.
3	WRENCH.	1.	W.I.
4	ROUND FLANGE	1.	C.I.
5	COTTER JOINT	1	W.I.
6	CHAIN END LINK	1	W.I
7	HANDLE	1.	BR'S
8	WOODRUFF KEY	1	W.I.
9	WASHER	1	W.I
10	TAP PIN	1	W.I
11	HAND WHEEL	1	C.I

PROB. 2. Make the drawings of a cotter joint, Fig. 374. Scale, full size. Taper of cotter is ½″ per foot.

PROB. 3. Make drawings of a nut wrench to dimensions given in Fig. 375. Scale, full size. For other sizes of wrenches see Table 7.

PROB. 5. Make drawings of a gib and cotter to dimensions given in Fig. 327. Scale, 3″ = 1 foot. *S* is the strap, *B* the brasses, *C* the cotter, *G* the gib, *R* the connecting rod, and *X* the set screw.

PROB. 6. Draw the "Woodruff" key, Fig. 373, for a 1½″ shaft. Take dimensions from Table 8.

PROB. 7. Draw the ball crank handle, Fig. 378, to the dimensions given. Scale, full size.

PROB. 8. Make drawings of chain and link and narrow shackle, Fig. 377. Scale, 4″ = 1 foot. Take dimensions from Table 11.

PROB. 9. Make drawing of taper pin, Fig. 64. Scale, full size. Taper of pin is ¼″ per foot. The finish curves at the end are made with a radius equal to the diameter. The material is steel.

PROB. 10. Make drawing of hand wheel, Fig. 65, outside diameter 6″. Scale, 6″ = 1 foot. Take remaining dimensions from Table 9.

PROB. 11. Make drawings of a washer for a 1½″ bolt. Take dimensions from Table 13. See Fig. 379.

PROB. 12. Make drawings of cast-iron flanges shown in Figs. 374 and 376 for a 1″ bolt. Scale, 6″ = 1 foot.

PROB. 13. Make working drawing of hand wheel, Fig. 381, 6″ diameter. Scale, 6″ = 1 foot.

PROB. 14. Make working drawing of shaft collar, Fig. 382; for a 2″ shaft. Scale, full size.

Machine Detail Sketches.

PLATES 35 AND 36.

These plates are to contain certain machine parts to be applied to the student by the instructor. Each object is to be sketched in orthographic projection on an 8×10″ sheet of cross-section paper with a 4H pencil. Use only one side of the paper. Sketch three views of each piece, viz., the elevation, plan, and right end view. All dimensions, notes, title, and finish marks must be neatly placed on the sketch.

Begin by drawing all the center lines for the front and end elevations and the plan. Make size of sketch to suit size of paper. Lines should be sketched very lightly and when sketch is approved and signed in pencil, the lines may be strengthened.

Put on all dimension lines before measuring the object. Measure with the two-foot rule and callipers. Callipers may be borrowed from the Instructor.

Sufficient dimensions must be placed on the sketch to enable the draftsman to make a working drawing for the pattern maker without having recourse to the object, after the drawing is commenced.

When a sufficient number of sketches have been made to fill one sheet of the usual size 15×20″, working drawings are to be made in finished pencil drawings. The finished pencil drawing must carry all dimensions, notes, finish marks, title, bill of material, and when approved and signed by the instructor it is to be traced on tracing cloth and blue printed.

PRESENT PRACTICE IN DRAFTING ROOM CONVENTIONS AND METHODS IN MAKING PRACTICAL WORKING DRAWINGS.

Summary Report of an Investigation made by the Writer with the Authority of the Armour Institute of Technology, Chicago, Ill., into the Present Practice of the leading Draftsmen in the United States, in the use of Standard Conventions and Methods when making Commercial Working Drawings.

A circular letter accompanied by a list of thirty-five questions was submitted to two hundred leading firms in the United States, embracing nearly all kinds of engineering practice.

The returns have been exceedingly gratifying, and especially so has been the spirit with which the "Questions" have been received and answered.

Many requests have been received from chief draftsmen for a copy of the returns.

The questions submitted and the answers received are given somewhat in detail below.

Q. 1. Do you place complete information for the shop on the *pencil drawing*, such as all dimensions, notes, title, bill of material, scale, etc.?

Complete information is placed on drawing before tracing.	57
Complete information is placed on tracing only	42
Principal dimensions and title only on pencil drawing	2
Draw directly on bond paper	10
Did not answer this question	10
Sometimes	7

Reasons given for making the pencil drawing complete:

To arrange notes. To save ime. The tracing is not usually made by the draftsman who makes the pencil drawing.

Q. 2. Do you ever ink the pencil drawing?

Never ink the pencil drawing	91
Generally ink the pencil drawing	7
Sometimes ink the pencil drawing	8
Sometimes ink the pencil drawing and shellac it for shop use.	1
Use bond paper	10
Make pencil drawings on dull side of tracing cloth	2
Ink center lines of assembly drawing	1
Ink center lines of pencil drawings in red	2

Q. 3. Do you trace on cloth and blue print?

Always trace on cloth and blue print	102
Blue print from bond paper	10
Blue print from bond paper occasionally	1
Sometimes make "Vandyke" prints for shop use	1
Sometimes use paper drawings in shop for jigs and fixtures.	1

Q. 4. Do you use blue prints entirely in the shop?

Use blue prints altogether in shop	105
Sometimes use pencil drawings or sketch	21

Sometimes use sketches made with copying ink	1
Sometimes use prints from "Vandyke"	1
Use white prints mounted on cardboard and varnished	1
Use blue prints mounted on cardboard	1
Use sketches for rush work	1

Q. 5. When tracing do you use uniform wide object lines? Ever use shade lines?

Use uniform, thick object lines. Never use shade lines	100
Sometimes use shade lines	21
Use shade lines on small details	5
Always use shade lines	14
Experts in the use of shade lines may do so to make drawings clear	1
Shade rounded parts	1

Q. 6. What kind of a center line do you use?

Long dash, very narrow, and dot, thus: ———— - ————	42
Long dash and two dots, ———— - - ————	29
Very fine continuous line, ————————	19
Very fine dash line, long dashes, ———— ————	8
Long dash and dot in red, ———— - ————	3
Continuous fine red line, ————————	8
Long dash and three dots, ———— - - - ————	1
Long dash and two dots, thus: ———— | | ————	1

Q. 7. What kind of dimension line do you use?

Continuous fine line, broken only for dimension ————	52
Fine long dash line, ————————	32
Fine long dash line and dot, ———— - ————	13
Fine continuous red line, ————————	8
Fine continuous blue line, ————————	4
Fine continuous green line, ————————	1

Same character of line as center line,	2
Dotted line, -	1
Long dash and two dots,——————— - - ———————	2
Heavy broken lines, ——————— ——————— ———————	1

Q. 8. What style of lettering do you use? Sloping? Vertical? Free-hand? All capitals of uniform height? or capitals and lower case?

Free-hand sloping	52
Free-hand vertical	45
Free-hand capitals, Gothic, uniform height	61
Free-hand capitals, and lower case	40
All caps, initials slightly higher	5
Lettering left to option of draftsman	2
Mechanical lettering, all caps	3
Not particular, the neatest the draftsman can make free-hand	4
Mechanical lettering, all caps, sloping	2
Give great latitude in lettering, only insist it be bold and neat	1
Roman, caps and lower case, free hand	2
Large letters $\frac{3}{16}$ths, small $\frac{3}{32}$ds and $\frac{1}{8}$th	2

Q. 9. Are your titles and bills of material printed or lettered by hand?

Lettered by hand	79
Standard titles printed and filled in by hand	12
Bill of material table printed and lettered by hand	12
Lettered by hand, contemplate having them printed	1
B. of M. typewritten on separate sheet and blue printed	8
Titles partly printed and filled in by hand	8
Use rubber stamp for standard title, fill in by hand	6
Standard title, bill of material lithographed on tracing cloth	8

Q. 10. Do you use a border line on drawings?

Always use border lines	97
Never use border lines	13
Use border lines on foundation plans, to send out	1
No border lines on detail drawings	1
Intend to discontinue the use of border lines	1
Border lines used only on design drawings	1
Only on drawings to be mounted on cardboard	1
Only used for trimming blue print	2
On assembly drawings only	1

Width of margins reported: 1″, ½″, ⅜″, ¼″, and ⅛″.

Q. 11. When hatch-lining sections, do you use uniform or symbolic hatch lines?

Standard symbolic lines	59
Uniform hatch lines for all materials	44
Shade section part with 4H pencil and note name of material	4
Symbolic hatch lines and add name of material	3
Uniform hatch lines for metal only	1
Uniform on details, symbolic on assembly drawings	5
Pencil hatch on tracings and note material other than cast iron	1
Uniform hatch lines, sometimes solid shading	1
No uniform system	1
Sections tinted with water colors representing the metals	1

Q. 12. Is the pencil drawing preserved? Is the tracing stored or do you make "Vandyke" prints for storing away?

Store tracings only	96
Pencil drawings preserved for a time	30
Pencil drawings preserved	13
White prints made and bound for reference	1
Tracings kept in office for reference, blue prints stored	9
"Vandyke" prints stored	1

Use "Vandyke" as substitute for tracing	2
Arrangement drawings preserved, detail drawings destroyed after job is completed. Pencil drawings used for gasket paper	1
Original pencil drawing inked and stored	1
Assembly drawings and layouts preserved	4
Patent office drawings preserved	1
Tried "Vandyke" but found it unserviceable, tearing easily	1

Q. 13. Do you use 6H grade of pencil for pencil drawings or what?

6H	73
4H, mostly for figures and letters	52
5H	16
Ranging from 2H to 8H	53

Q. 14. Do you use plain orthographic projection for free-hand sketches? Ever use perspective or isometrical drawing for sketches?

Plane orthographic 3d angle projection	99
Isometrical drawing for sketches	25
Perspective for sketches	1
Isometric for piping layouts and similar work	8
Perspective and isometric for catalogue work	2
Isometric sometimes	6
Never use free-hand sketches	6

One says, "When we run into other than orthographic, men are too timid and not sure of themselves. In perspective drawings when work is cylindrical, workmen get mixed up on center lines.

Q. 15. What sizes of sheets do you use for drawings?

9″×12″	13
12″×18″	16

18″×24″	20
24″×36″	19

There seems to be little uniformity in the sizes of shop drawings, about 67 firms reporting different combinations. A few have no system but simply make the size of sheet to suit the object to be drawn.

Q. 16. Do you use red ink on tracings?

Never use red ink on tracings	57
Recently discarded the use of red ink	2
Use red ink for pattern figures	1
Use red ink for center and dimension lines	8
Use red ink for check marks	1
Use red ink for existing work on studies	1
Use red ink sometimes	2
Use red ink on occasions when it is desired to show old work in red and new work in black (use carmine)	1
Use carmine for brick	1

Qs. 17 and 27. How indicate finished surfaces on drawings? When finished all over? When "file finished," ground, planed, bored, drilled, etc.?

Finished surfaces indicated as in Fig. 1	65
Finished surfaces indicated as in Fig. 2	16
Finished surfaces indicated as in Fig. 3	8
Finished surfaces indicated as in Fig. 4	2
Finished surfaces indicated as in Fig. 5	2
Bound the surfaces with red lines	2
Bound the surfaces with dotted lines	2
Name the finish by note in full	68
Do not specify machinery method	6

(See drawing.)

Q. 18. Do you use horizontal or sloping lines for convention in screw threads?

Sloping lines, see Fig. 6	94
Horizontal lines, see Fig. 7	12
Horizontal lines, see Fig. 8	13
Both	7
Neither, but as shown in Fig. 9	1
Neither, but as shown in Fig. 10	1

FIG. 1.

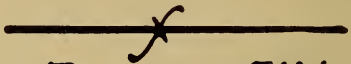


FIG. 2.

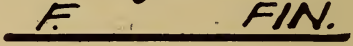


FIG. 3.

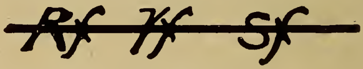
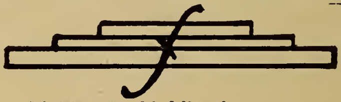
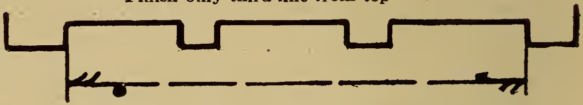


FIG. 4.



Finish only third line from top

FIG. 5.



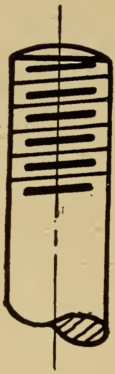


FIG. 6.

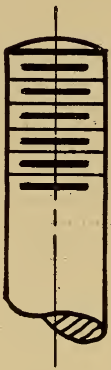


FIG. 7.

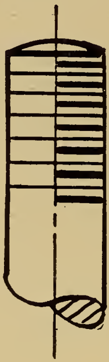


FIG. 8.

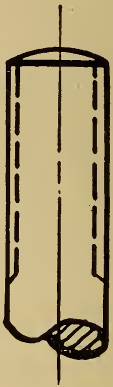


FIG. 9.

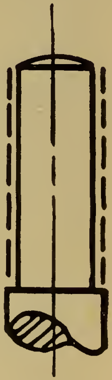


FIG. 10.

Q. 19. When a large surface is in section do you hatch-line around the edges only?

Hatch-line edges only	62
Sometimes	3
Hatch section all over	54
Do not use hatch lines; shade the whole surface with 4H pencil	3
Usually show a broken surface line	1

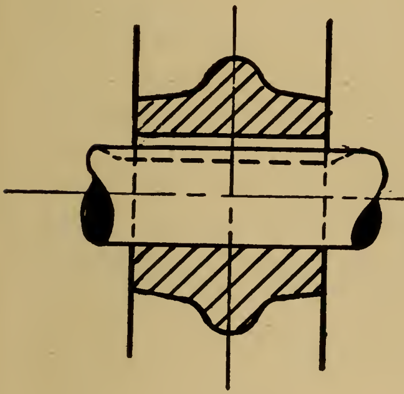


FIG. 11.

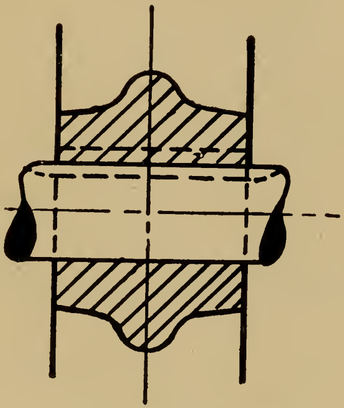


FIG. 12.

Q. 20. Do you section keyways in hubs or show by invisible lines?

Section keyways as shown in Fig. 11	73
Show keyway by invisible lines, see Fig. 12	40
Keyways in hubs left blank	1

Q. 21. In dimensioning do you prefer to place the dimension upon the piece or outside of it?

Outside whenever possible	92
Upon the piece	13

Both, according to size and shape of part	19
No rule	1

Commenting on placing dimensions outside of piece one says, "It entails less confusion to workman." Another says: "So as to make detail stand out."

Q. 22. Do you use feet and inches over 24 inches?

Yes	69
Use feet and inches over 36″	4
Use feet and inches over 24″ on foundations and outlines	2
Use feet and inches over 48″	6
All inches	21
For pulleys use inches up to 48″	1
Inches up to 10 feet	2
Start feet at 24″ thus: $2\overset{\prime}{-}0''$	2
Usually, but not always	2
Yes, except pitch diameters of gears, which are all given in inches	2
Yes, except in boiler and sheet iron work	3
Use feet and inches over 12″	6
Inches up to 100″	3
Inches up to 60″	1

Q. 23. How do you indicate feet and inches? Thus 2 ft. 4″, or thus $2\overset{\prime}{-}4''$?

$2\overset{\prime}{-}4''$—97, $2^{\text{FT.}}$ 4″—5, 2 FT. 4″—2, 2ft. 4″—13. Both 2ft. 4″ and $2\overset{\prime}{-}4''$—1, 2FT. 4 IN.—1, 2′ 4″—8, $2\overset{\smallsetminus}{-}4^{\smallsetminus\smallsetminus}$—1.

Q. 24. Do you dimension the same part on more than one view?

One view	94
More than one view as check	46

Q. 25. When several parts of a drawing are identical would the dimensioning of one part suffice for all, or would you repeat the dimension on each part?

One part only	82
Would repeat or indicate by note	39
"Left to judgment of draftsman"	1

"When it is evident that several parts are identical the dimensioning of one part would suffice, 'Would never leave room for doubt.'"

Q. 26. Do you write R for radius or RAD.? D. for diameter or DIA.?

RAD .. 35	Rad . . . 47	R 32	rad. . . 1	r 3
DIA .. 41	Dia . . 48	D. . . . 15	d 3	dia . . . 4
DIAM 1	Diam. . . . 3	diam 5		

Do not use R. or RAD., dimension only	1

Q. 28. Do you always give number of threads per inch? When you do how are they indicated?

Only give number of threads when not standard	67

All others always indicate number of threads in a great variety of ways. A few of the different styles of noting the threads are given below:

¾″—10 Thr. 5 THDS. PER 1″. 8thds. 4 threads per inch. Mach. Screw 10–24, 1¼″ XII, 16 P. RH. Vth. U. S. S. XVIII, 1″–8–U. S. S. 1″ TAP, 8 PITCH, 3 TH'D R. H. SQ. DOUBLE, 5″–18 THDS. R. H. OWN ST'D 10 thds. per inch. For pipe tap thus, ½″ P.T., etc., etc.

Q. 29. How do you "Mark" a piece to indicate on the bill of material?

Number it on drawing and put a circle around it	34

By name or letter	35
By pattern number	2
By symbol and number	14

Castings, I, II, III, Forgings, 1, 2, 3.

Q. 30. When a working drawing is fully dimensioned why should the scale be placed on the drawing?

For convenience of drafting room	25
Check against errors	11
Not necessary	18
Scale not placed on shop drawings	18
For convenience in calculations and planimeter work	1
To give an idea of over-all dimensions when these are not given. "We never saw a drawing so fully dimensioned as to warrant leaving off the scale"	2

"If a drawing is to scale the scale should be on the drawing, whether it is needed or not."

"It gives every one interested a better conception of the proportions of the piece, and there are frequently portions of a design which do not require a dimension for the shop to work to, and which it is interesting to scale from an engineering point of view."

"To get approximate dimensions not given on drawing."

"Impractical to dimension all measurements for all classes of work."

"Scale will tell at a glance, dimensions would have to be scaled."

"To obtain an idea of relative size of parts without scaling the drawings."

"To sketch on clearance." "To proportion changes." "When erecting to measure over-all sizes."

"In case a dimension has been left off, the scale will help out."

"This is a question of opinion; some will not have the scale, others insist on it." "We always give the scale."

"It is an immense help and time saver in the drawing room."

"Generally no reason. In our work we combine standard apparatus by 'fudge' tracing, and it is convenient to know scale so all parts will surely be to same scale."

"In discussing alterations, additions, clearances, etc., it is convenient to know the scale instantly."

"For convenience in drafting room. We often put an arbitrary scale on with a reference letter indicating scale to draftsman."

"To give toolmaker an idea of the size of the finished piece."

"As an aid to the eye in reading."

Above are some of the reasons given for placing the scale on the drawing. Below are given a few of the reasons why some do not place the scale on the drawing.

"Scale should never be used in shop," says one.

"Not necessary. Sometimes drawing is made out of scale."

"Not advisable, on account of workmen getting into the habit of working to scale instead of to the figures."

"Know of no good reason at all."

"Believe it best to leave scale off."

"Should not. Drawing should never be scaled."

"Know of no good reason why it should be."

"Should not be given on drawing."

"Do not object if left off, not needed."

Q. 31. Do you use the glazed or dull side of tracing cloth?

Dull side . . . 66 Glazed side . 32 Both 4

"Dull side, because it lies flat better in drawers."

"Dull side, so that changes which may be necessary while work is under construction, can be made easily in pencil and later in ink."

"Dull side so tracings may be checked in pencil."

"It prevents curling."

"Both, although the glazed side when traced on lies better in the drawer."

"We use cloth glazed on both sides, work on convex side, so that shrinkage of ink will eliminate camber."

"Dull, except for U. S. Government, who requires the glazed side to be used."

Q. 32. How do you place pattern numbers on castings?

Pattern number with symbol or letter is placed on or near the piece, e.g., PATT.–D–478–C	36

This question was not happily stated: most answers gave "raised letters cast on," while the question like all the others refers to the marking of the drawing.

Q. 33. How do you note changes on a drawing?

On tracing with date	32
New tracing and new number	17
Put a circle around old figure and write new figure beside it with date	8
Make new tracing	5
Red ink with date	8
Use rubber stamp "Revised" with date, and indicate changes on record print	28
Use change card system	1
Special forms for purpose. Change made in a book with date. New prints made to replace. In place at title with draftsman's initials and date	8

Q. 34. Do you place dimensions to read from bottom and right hand, or all to read from bottom, or how?

Bottom and right hand	103
From bottom only	2
No fixed rule	2
From R to L and bottom to top	1

Q. 35. Do you always make a table to contain the bill of material?

Yes........	49	No	25	Not always. .	5
Usually	1	Use separate bill	32		

Bills on general drawings only. On details number is marked on piece.

"No, but it is advisable to do so." "Have abandoned that system."

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